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FACETS OF INDIAN ASTRONOMY

(A collection of Articles of Prof. K.V. Sarma)

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" Centre of Excellence in the Subject of Traditional Sastras"

FOREWORD

It is being slowly admitted by the scholars and scientists of the world that most of the significant inventions or discoveries made by the scientists in the recent past in various branches of science and technology have their moorings in ancient Sanskrit Literature that made its appearance with the revealation and compilation of the Vedas in this sacred land of ***Bharat***. This unique historic intellectual development of the mankind in India can roughly be corresponded with the dawn of a civilized and cultured human society on the surface of the Earth. The historians, despite their continuous efforts and intellectual exercises to determine the appropriate period of the golden era of the revelation of the Vedas in India, fail to reach a consensus meaning thereby the Sanskrit literature is probably the ancient-most literature in the world. Several meaningful works in various languages including English & other foreign languages produced so far by both eastern as well as western scholars, have substantiated a fact beyond doubt that various streams of science and technology such as Physics, Chemistry, Biology, Engineering, Medicine, Computer Science, Agriculture and others have drawn their origin from the concepts, nomenclature, contemplations and theories developed by the ancient seers and savants of this country in their monumental works written in Sanskrit. Such two important branches of modern science are space-related Astro-physics and Mathematics that directly correspond with ***Jyotisham*** and ***Ganitam*** respectively.

In view of the outstanding contributions made by our ancestors like ***Aryabhatt, Bhaskaracharya, Brahmagupta, Lilavati, Samanta Chandra Shekhara*** to name a few, in these two important branches of science, our country has been adjudged as an advanced centre of scientific learning and research in these two areas. Needless to mention that Professor K.V.Sharma, former Director, Institute of Sanskrit and Indological Studies, Hoshiarpur, Punjab University, who completely dedicated his life and career to find out this truth, is acknowledged as a pioneer researcher in this field in twentieth century. A doyen of Sanskrit literature and an unparalleled master on indological studies, Prof. Sharma has written nearly three hundred books and six hundred research articles to his credit in various subjects including an area that intends a synergy of both modern scientific knowledge and ancient Indian lore. The present book **"Facets of Indian Astronomy"** is a precious collection of articles of Professor K.V.Sharma.

While expressing our gratitude to the learned members of the Editorial Board for their endeavour in collecting these articles and preparing this volume, we deem it a proud privilege to bring out this book on behalf of our University, which, I am confident, will further enhance the status of our Institution, already accredited at A^+ grade by NAAC and recognized as Centre of Excellence by the U.G.C. No doubt, most of the articles, found place in this book, were published in various journals and magazines earlier and some of them were presented in national and International Seminars and Conferences; but availability of all these research papers on a particular thrust area i.e. Indian Astronomy, has been ensured through the publication of this volume for all categories of readers and researchers interested in the subject. My special thanks are due to all the members of the Department of Research & Publication of our University but for whose constant efforts and intellectual exercises, this volume would not have seen the light of the day.

Harekrishna Satapathy

(Harekrishna Satapathy)
Vice-Chancellor

INTRODUCTION

ज्योतिषं चक्षुषी वेदस्य

ASTRONOMY THE EYES OF THE VEDA

I

Since ancient times, great importance has been attached to the performance of Yajñas (ritual sacrifices) in the Vedic religion. Even the Vedas are said to be revealed for performing the Yajñas:

वेदा हि यज्ञार्थमभिप्रवृत्ताः कालानुपूर्वा विहिताश्च यज्ञाः।
तस्मादिदं कालविधानशास्त्रं यो ज्योतिषं वेद स वेद यज्ञान्।।

(*Ārcajyotiṣam* 36; *Yājuṣajyotiṣam* 3)

"The Vedas have indeed been revealed for performing the sacrifices and these sacrifices are to be performed at laid down times. Therefore, he who knows the science of time namely *Jyotiṣa*, under-stands the sacrifices."

It is thus clear that development of astronomy in ancient India was helped by religious needs. Also for finding the prescribed instant and duration of time, attention must have been paid to measurement of time accurately. The *Śatapatha Brāhmaṇa* (XII. 3. 2. 5) contains a very minute division of time according to which a *Muhūrta* (=48 minutes) is further divided into subunit called *Kṣipra*, *etarhi*, *idāni* and *prāṇa* successively. The scale of division is 15, so that there will be 50625 *Prāṇas* in a *Muhūrta* (This will make a *Prāṇa* to be less thantime of the day and the like. Being a complicated precision instrument, it was used to be prepared by hereditary families of experts with graduations and words inscribed in Persian script. As the instrument grew popular in the land, it began to be inscribed in *Devanāgarī* script, as well. Short works in Sanskrit also came to be composed describing the construction and use of astrolabes. The earliest work on the astrolabe is the *Yantrarāja* (1370),

mentioned earlier based on Arabic sources, by Jaina Mahendrasūri, court astronomer of Frozeshah Tughlaq, in five chapters entitled *Gaṇita, Ghaṭanā, Yantraracanā, Yantraśodhana* and *Vicāraṇā*. There are commentaries on the work by Malayendusūri and Gopīrāja.

Other works on the subject, of a later period, include those of Malayendu (with Cintāmaṇi's commentary) and by Mathurānātha and some anonymous, but by far the most important is the *Yantrarājaracanā* by the royal astronomer Sawai Jai Singh and its rendering into verse form by Śrīnātha under the title *Yantraprabhā*, over which its modern editor Kedaranatha has added his own commentary, *Yantrarājaprabhā*. A number of Indian astrolabes, of different types, combinations and functions are preserved in museums and other repositories and await detailed study.[44]

The efforts of the Rājā Sawāi Jai Singh of Jaipur (1686-1743) towards the fostering of scientific observational practices with the combined use of Hindu, Muslim and European advances in astronomy are a saga in itself in the history of Indian astronomy. Jai Singh collected texts of all the three traditions studied them himself and composed works, invited scholars of all the traditions and induced them to prepare original works and translations. He also invented and caused to be constructed instruments for astronomical observations. A manuscript entitled *Yantraprakāra*, preserved in the Art Gallery as No. 31 of the Mahārājā's Museum at Jaipur, mentions the under mentioned instruments as designed by Jai Singh with the caption: *Śrī-mahārājādhirāja-viracita-yantrāṇi*: (1) *Jayaprakāśa-yantra*, (2) *Nāḍīvalaya*, (3) *Krāntivṛttam*, (4) *Palabhāyantra*, (5) *Digaṃśayantra*, (6) *Śarayantra*, (7) *Agrayantra*, (8) *Yāmyottaramiti*, (9) *Jatulahalaka*, (10) *Yantrarāja* (astrolabe, mentioned above), (11) *Jātuśukavataina*, (12) *Sudasphakarī*, (13) *Jātuśukataina*, (14) *Śaṅkuyantra* and (15) *Pratirāśinām krāntivṛttāni*.[45] The main features and methods of observation of some of one-seventeenth of a second slightly).

The tradition of *Jyotiṣa* is very much part of Indian life and culture even today. A study of its historical perspective and of its connections with Indology in general is quite desirable.

As the performance of sacrifices was an integral part of Vedic life, the associated activities reflect a panoramic view of ancient Indian society. It has been even said that the *Yajñaśālā*s (sacrificial halls) "constituted the earliest observatories, laboratories and synods of our science and culture."

In ancient India all arts and sciences were regarded to have a divine origin. The *Nāradapurāṇa* (ch. 54) states that *Jyotiṣa* was enunciated by Brahmā in antiquity. The *Garuḍapurāṇa* (59.1) similarly states that the *Jyotiṣa* science of 4 lac verses was communicated to god Rudra by Keśava. Often the attribution of divine origin to works or to subject matters is considered to be due to the philosophical attitude (of being indifferent to worldly gains) of Indian mind. But frequently the practice is for securing authority and antiquity for one's own work and findings. Any way the practice deprives us from knowing the actual author and time thereby harming the cause of history of science and education.

As expressed by the popular verse :

शिक्षा कल्पोऽथ व्याकरणं निरुक्तं छन्दसां चयः ।

ज्योतिषामयनं चैव वेदाङ्गानि षडेव तु ।।

The Indian *Jyotiṣa-śāstra* (Astronomy, Astrology and Mathematics) is considered to be one of the six *Vedāṅga*s ("limbs of *Veda* or *Veda-puruṣa*"), which help in study and interpretation of the Vedas. The astronomical sciences are the eyes of the Veda. They stand at the top of Vedic sciences as is clear from the verdict *mūrdhani sthitam* (*Ārca Jyotiṣam* 35; *Yājuṣa Jyotiṣam* 4).

II

We are living in an era of science and technology. But the modern achievements in the field of science and technology have not

come into existence overnight. They were neither dropped as a bolt from the blue nor are the product of some magical tricks. The present stock of scientific and technological knowledge has been achieved after centuries of efforts by many scientists working ceaselessly. The thrilling story of real adventures of scientific inventions and discoveries is interesting and exciting. A study of history of science is not only intellectually enlightening but also beneficial in many other ways. There is always a fresh manifestation of life when we look into historical perspectives. In general, since the future has to be moulded out of the past, the more we study the past the more glorious will be our future.

The full history of exact sciences (such as *jyotiṣa* sciences) of India can be written only after a comprehensive survey has been made of the manuscripts available in Sanskrit and vernacular languages and of the dates having bearing on them. The famous *New Catalogus Catalogorum* does provide a ready reference tool for detailed information about Sanskrit authors and works on all subjects. In the field of Astronomy, astrology and mathematics, Dr. David Pingree's *Census of Exact Sciences in Sanskrit* is quite exhaustive. Five volumes of series A of the CESS, covering authors up to the semi vowel V, have been already published (unfortunately Pingree died recently).

A genuine history of astronomy in India is to be based on the primary (whether published or in manuscript form) as well as on the secondary sources, which should include not only books but also research papers, and even the relevant unpublished doctoral theses. For sound knowledge and critical analysis one must stand on the 'Shoulders of Giants'. Doubtlessly the late Prof. K.V. Sarma was such a giant scholar.

During the Muslim rule in medieval North India, there was a sort of decadence of culture and the creative spirit in arts, science, and literature was adversely affected. The south was comparatively less disturbed and significant original work on traditional lines continued there especially in exact sciences both in quality and quantity. The

famous late *Āryabhaṭa* School flourished in south India (especially in Kerala) where many new heights were attained. The level of advancement in mathematical sciences in India during the period (covering the 14^{th} to the 17^{th} centuries) is rightly called "The Golden Age of Indian Mathematics".

The astronomers of the Late Āryabhaṭa School were the followers of the renowned Āryabhaṭa (born A. D. 476). Their efforts have been generally directed towards supplementing Āryabhaṭan astronomy and mathematics and deriving more accurate methods and results. The present collection includes quite a few articles on Āryabhaṭa and his work.

Eminent astronomer-mathematicians of the late *Āryabhaṭa* School of Kerala include the following:

1. Mādhava of Saṅgamagrāma (C. 1350-1425) who is regarded as the founder of the School.
2. Parameśvara of Vaṭaśreṇī (C. 1360-1460), pupil of Mādhava.
3. Dāmodara (C. 1410-1510), son of Parameśvara.
4. Nīlakaṇṭha Somayāji (1444-1545), pupil of Dāmodara.
5. Citrabhānu (C. 1475-1550).
6. Śaṅkara Mahiṣamaṅgalam (C. 1494-1570).
7. Jyeṣṭhadeva (C. 1500-1610) pupil of Dāmodara and Nīlakaṇṭha.
8. Śaṅkara Vāriyar (C. 1500-1560). pupil of Nīlakaṇṭha and Jyeṣṭhadeva.
9. Nārāyaṇa Mahiṣamaṅgalam (C. 1540-1610).
10. Acyuta Piṣāraṭi (C. 1550-1620), pupil of Jyeṣṭhadeva.
11. Putumana Somayāji (C. 1660-1760).
12. Śaṅkara Varman (C. 1799-1839).

A large number of original works and commentaries in Sanskrit and Malayalam were written by above and other astronomers in the field of *Jyotiṣa-śāstra*. Modern historians and other scholars in the field will ever remain grateful to Prof. K. V. Sarma for editing and translating several of these works. In fact, research in the field got a great boost due to his untiring efforts. Moreover, Dr Sarma's research papers and other articles included in the present volume are equally important because they contain rich information and masterly critical analysis. They will provide not only and introduction but strong foundation for further investigations based on original sources. In fact his work has inspired many scholars in the field and will continue to do so.

III

The *Kaṭapayādi* alphabetic system of numerals was very popular among Kerala astronomers. As the name implies it can be briefly stated by the phrase, *Kādi nava, ṭādi nava, pādi pañcaka, Yādyaṣṭaka*. Also ñ, n (with vowels), and free vowels denote 0, while free consonants are to be ignored (Dravidian ഴ is 9), Nīlakaṇṭha Somayāji's birth date is given by the chronogram *tyajāmyajñatāṃ tarkaiḥ* which yields the number 1660181 in the above system by the usual right to left convention. The number represents *Kali ahargaṇa* (number of days since the advent of the *Kali* or Iron Age) and corresponds to a day in middle of A. D. 1444. An interesting case is that of the verse,

नदीपुष्टिरसह्या नु न ह्यसारं पयोऽजनि।
निजात् कुटीरात् सायाह्न नष्टार्थाः प्रययुर्जनाः ।।

In this all the four quarters (of the verse) give the same number 01721180 (but we have to follow left to right rule for 2nd and 4th quarters). The verse is attributed to *Nārāyaṇa Bhaṭṭa* (pupil of *Acyuta Piṣāraṭi)* and the *Kali* chronology refers to flood in Bhāratappuḷa in A. D. 1611.

The marvelous decimal place-value system of numeration is India's foremost scientific gift to the world. The use of modern science of trigonometry based on the sine function is another mathematical gift of India to the world (earlier Greek trigonometry was based on

chord function). In this connection, we have a very interesting historical narration involving cultural contacts. The usual Sanskrit word for sine is *Jyā* or *Jīvā.* When Indian astronomical works were translated into Arabic at Baghdad in 8th century A. D., the technical term *Jīvā* (which was new to the Arabs) was written as such J-y-b.

When the Arabic version of a Sanskrit work was further translated into Latin in the 11th century Spain, the Arabic transliteration J-y-b (since it was new thing there) was confused with the Arabic word *Jaib* or *Jeb* (जेब) which means pocket. So it was translated into Latin as sinus ('cavity' or 'pocket'). In due course Latin *sinus* became 'sine' in English, Finally, when modern western education was introduced in India, students here learnt the sine function in trigonometry. Thus it was the original Sanskrit word and trigonometric term *Jīvā*.which came back to India after a journey of 1000 years, in the unrecognizable form *sine* !

It should be noted that mathematical methods used in Indian *Siddhāntic* astronomy are mostly based on sine or derived functions *(jyā-gaṇita),* Solution of astronomical triangles and other problems was often obtained by the technique of 'working inside the celestial globe'. A remarkable feature of the Kerala School of astronomy was that efforts were made to tally results of computation with those of observation. New astronomical theories and parameters have been proposed. There was no prosecution in India like that of Galileo in Europe. Nīlakaṇṭha's *Jyotirmīmāṃsā* is a unique work in the context.

SSES Research Centre has done a valuable service to scholars by bringing out this Facet. I am sure that the Research Centre will soon get wider reputation for excellent work it is doing.

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2009

PREFACE

Our country has been a source of knowledge in so many branches of learning from the time of the Vedas. Not only that people were involved in meditation, *tapas*, religious austerities or spending their time appreciating nature and making literary compositions, but were also given to serious scientific inquiries. In fact, this was given the status of a *Vedāṅga* or *Upāṅga*.

That way, development of Astronomy and Mathematics is one of the prides of India. Our ancestors have made so many contributions that they were ahead of their western counterparts by at least a thousand years, in this and many other fields like metallurgy, medicine, etc. The Sanskrit word *Jyotiṣa* generally is misunderstood to mean astrology, though originally its started off as Astronomy. The word is derived from *Jyotiḥ* (*padārtha*) meaning luminous bodies (found in the sky) and the *Śāstra* dealing with them after keen observation of them is *Jyotiṣa*. Thus Astronomy was developed, as a *Vedāṅga* to facilitate calculation of time, and the right time to perform the Vedic rituals and *Laukika karma*.

Since this needed not only keen observation of the celestial bodies but also a lot of calculations, there was also a lot of development in mathematics. Thus we find a parallel development both in Astronomy and Mathematics. There were both heliocentric and geo-centric views of the world. Nonetheless the calculations were perfect and also accurate predictions could be made about lunar and solar eclipses, which are a real marvel, given the highly haphazard path of the moon in the back drop of the stars.

Most of the authors were both Astronomers and Mathematicians making significant contributions to both the fields. There were luminaries like Āryabhaṭa, Bhāskara I & II, Varāhamihira, Brahmagupta, Nīlakaṇṭha Somayājī, Parameśvara to name only a few, who were stalwarts and some of whose contributions have found place into text books, without any acknowledgement, however.

These sciences were growing even when our country was under the shackles of Muslim rule and many works were also being translated into Arabic or Persian, which were later translated into Latin and other

western languages. But subsequently with advent of English education in India the study of ancient Indian sciences was overshadowed.

It is a matter of great pride that vast literature in Indian Astronomy has been produced in India. A survey of literature on Astronomy conducted and prepared by David Pingree with the title: "*Census of the Exact Sciences in Sanskrit*", in five Volumes (up to letter व, Published by American Philosophical Society, Philadelphia.) bears testimony to this fact. His survey reveals that there are more than one lakh manuscripts in *Jyotiṣa* (including Astronomy and Astrology) which are available in India and abroad. However, the number of works published or studied so far has been very less compared to the enormous wealth of source materials.

In the backdrop of this scenario, the present book "*Facets of Indian Astronomy*" (a collection of selected articles of Prof. K. V. Sarma) is a milestone in the field of research and scientific study of Indian Astronomy. This work highlights various aspects of Indian Astronomy which have been crystallized in the traditional learning.

Prof. K. V. Sarma, a pioneer in this field has made all efforts to bring out the salient features of Indian Astronomy in various research papers, which has earned him name and fame. The present work, no doubt, will bridge a gap in understanding traditional and modern Astronomy and Mathematics.

Scholars interested in this branch of learning will definitely take interest to know our ancient thoughts in understanding and calculating the movement of celestial bodies and also their impact on human life.

It is our great hope that this book will kindle the young minds to think more and take up studies in this area to establish our rich heritage and culture as a worthy inheritor of this great ancient Indian tradition. I am thankful to Rashtriya Sanskrit Vidyapeeth, Tirupati for their kind consideration to publish this book.

Prof. Siniruddha Dash
Hon. Director,
SSES. Research Centre, Chennai

2009



Prof. K.V. Sarma
1919 - 2005

PROF. K. V. SARMA

(Krishna Aiyer Venkateswara Sarma)

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B.Sc., The Maharaja's College of Science, Trivandrum(1936-40)

M.A.(Sanskrit), University of Kerala, Trivandrum, (1940-42)

D.Litt. (Sanskrit): Punjab University on *Contributions to the Study of the Kerala School of Hindu Astronomy and Mathematics.*

Research Scholar: Manuscripts Library, University of Kerala (1942-43)

Supervisor : Manuscripts Cataloguing Section, ORI and Mss. Library, University of Kerala (1943-51)

Research Assistant : New Catalogus Catalogorum, Dept. of Sanskrit, Madras University (1951-57)

Lecturer : Dept. of Sanskrit, Madras University (1957-62)

Curator : Research and Library Dept., Vishveshvaranand Vedic Res. Inst., Hoshiarpur, Punjab (1962-65)

Lect. Cum Asst. Editor : Inst. of Sanskrit and Indological Studies, Hoshiarpur, Punjab University (1965-72)

Reader : Inst. of Sanskrit and Indological Studies, Hoshiarpur, Punjab University (1972-75)

Acting Director: Inst. of Sanskrit and Indological Studies, Hoshiarpur, Punjab University (1975-77)

Director cum Professor: Inst. of Sanskrit and Indological Studies, Hoshiarpur, Punjab University (1977-80)

Hon. Professor : Inst. of Sanskrit and Indological Studies, Hoshiarpur, Punjab University (1980-83)

Hon. Professor of Sanskrit: Adyar Library and Research Centre, Adyar (1983-)

Director : Sree Sarada Education Society Research Centre, Adyar (1997-2005)

RESEARCH CONTRIBUTION

BOOKS

More than 100. Some of them are:

A History of Kerala School of Hindu Astronomy, VVRI, Hoshiarpur, 1972.

Goladīpikā of Parameśvara, Adyar Library and Research Centre, 1957.

Līlāvatī of Bhāskarācārya with Com. Kriyākramakarī of Śaṅkara and Nārāyaṇa VVRI, Hoshiarpur, 1975

Ārayabhaṭīya of Āryabhaṭa, INSA, New Delhi, 1976.

Tantrasaṅgraha of Nīlakaṇṭha, VVRI, Hoshiarpur,1977.

Indian Astronomy : A Source Book (with Subbayyappa), Nehru Centre, Bombay, 1984.

Pañcasiddhāntikā of Varāhamihira. PPST Foundation, Madras, 1993.

Gaṇitayuktayaḥ. VVRI, Hoshiarpur, 1979.

Vīṇāvāsavadattakathā, KSRI, Chennai, 1962.

Vivekacandrodaya Nāṭaka, VVRI, Hoshiarpur, 1966.

Praśastikāśikā, VVRI, Hoshiarpur, 1967

Pāṇḍyakulodaya, VVRI, Hoshiarpur, 1981

Science Text in Sanskrit in the Manuscripts repositories of Kerala and Tamilnadu, RSKS, New Delhi, 2002.

Gaṇita Yukti Bhāṣā of Jyeṣṭhadeva, Indian Institute of Advanced Study, Simla, 2003.

Bṛhatsaṃhitā of Varāhamihira, RSKS, New Delhi, 2006.

RESEARCH PAPERS

More than 600 covering the subjects Veda, Dharmaśāstra, Astronomy, Indology, Manuscriptology etc.

AWARDS

Mahāmahopādhyāya - Maithili University, Darbhanga, 1977

Certificate of Honour for Sanskrit - Govt. of India, 1992

Vidyābhūṣaṇam - Kerala Sanskrit Academy, Trichur, 1993

International Man of the Year 1997 by International Biographical Centre, Cambridge, England, 1997

Life Time Achievement Award - United Writers Association, Madras, 1998

Outstanding People of the 20th Century for contribution to Education, Sanskrit and Manuscriptology by International Biographical Centre, Cambridge, England, 1998.

2000 Millennium Medal of Honour by American Biographical Inst. U.S. 1998.

Vācaspati title conferred by Rashtriya Sanskrit Vidyapeeth (Deemed University), Tirupati, 2003.

Vedaśrī title conferred by Veda Adhyayana Kendra, Bangalore, 2004.

CONTENTS

PART - I

PART - II

PART - I

ARTICLES

A SURVEY OF SOURCE MATERIALS*

Fascinating phenomena in nature like the brilliant moonlit sky studded with stars, the charm of the rising and setting sun, the waxing and waning phases of the moon, the periodical changes in the seasons and the like should obviously have excited the curiosity of early man. The origins of astronomy in India, as else where in the world, have to be traced to the inquisitive interest which such phenomena excited in him and urged him to investigate the how and why thereof. The evolution of astronomical acumen, naturally enough, passed through several stages including the feeling of wonder, mystery, continued observation, religious speculation, cosmic interpretation, scientific inquiry, derivation of rules for computation and development as a discipline.

The present survey of source materials on Indian astronomy is intended to indicate, in a chronological manner, the primary and secondary sources bearing on the development of the science of astronomy in India from the earliest times. Astronomy, unlike certain other disciplines like architecture and metallurgy, is more a science of observation and computation and therefore the main sources of information on its history have to be sought for in recorded literature, traditional practices, instruments and observatories, the last two relating to medieval and post-medieval periods.

Archaeological Sources :

Large-scale excavations in the different regions of the Indian sub-continent especially in the north-western region, during the last one hundred years, have unearthed substantial archaeological materials right from the Early Stone Age through the Middle and Late Stone Age to historical times. In the Mediterranean world Neolithic culture, wherein sharp stone implements were used, and the chalcolithic culture, wherein copper and bronze implements had come into vogue, are

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**History of Astronomy in India*, Ed. S.N. Sen & K.S. Shukla, INSA. New Delhi, 1985.

clearly distinguished. In India, however, the two are often found to co-exist. This aspect was first identified in the excavations at Mohenjodaro and Harappa in Pakistan and Punjab on the Indus basin, for which reason that culture was called Indus Valley Civilization. Later excavations proved the existence of this culture in places far removed from the Indus basin, extending to the entire north-west of India and part of Pakistan. The area included Cutch, Saurashtra and Gujarat in the south, Sind and Baluchistan in the west, East Panjab in Pakistan and Punjab and Western U. P. in India, in the north and northern Rajasthan in the east covering in all about 80,000 square miles. A series of excavations at Harappa have determined the norms of the civilization that existed in the area for which reason it is generally given the appellation Harappan Culture. With this culture as the basis, the archaeological finds at Mohenjo-daro (Sind), Kot Diji (Sind), Kalibangan (Rajasthan), Lothal (Gujarat) and nearly 70 other sites, at different levels, are generally classified as Harappan, pre-Harappan and post-Harappan. Many of the finds have been subjected to Carbon-14 tests which have given dates ranging from 2300-2000 B.C.[1] Since recent researches have shown that radio carbon dates tend to be lower beyond 1000 B.C., the date of the Pre-Harappan culture might have to be shifted to a few centuries earlier, to about 2500 B.C. or earlier.

Apart from extensive material including different types of pottery, stone and metal implements, faience, glass and beads, the above excavations have unearthed massive remains of towns and fortifications and nearly 3000 inscriptions and figures on terracotta seals[2]. Since during the early days of the evolution of astronomy observations would have been restricted to simple contrivances, besides the human eye any substantial remains could not be expected from archaeological sources. It is in the orientation indicated by the remains of constructions and the interpretation of select seals that one could look for any remains of astronomical importance[3]. However, more important and informative than the archaeological sources are the astronomical traditions of the earliest times recorded and preserved in Vedic literature the early strata of which go farther back than the excavated remains indicated above.

VEDIC LITERATURE

Nature of the Vedic corpus

The extensive Vedic literature spread over nearly 300 basic texts, forms, amongst other things, the primary sources of information about the earliest stages of astronomical knowledge in India. A grand monument of the hoary past of the land, the Vedas have come down in a continuous and unbroken tradition, much better preserved than the religious literature, of any other ancient civilization. While most other religious canons have been composed at some specific period by an individual or a school, the Vedas are said to be revealed to 'Seers' of different ages, and handed down intact from generation to generation by oral transmission. This literature is amenable to be divided broadly, by contents and chronology, into four, viz. the *Saṃhitās, Brāhmaṇas*, *Āraṇyakas*, *Upaniṣads* and *Vedāṅgas*.

The *Saṃhitā*-s

The *Saṃhitā*s are collections of hymns, prayers, invocations, charms, sacrificial formulae and the like, selected from a vast mass of floating material and arranged and classified according to content, utility or some other consideration. For each hymn or prayer so included, such documentation as its Seers, the deity invoked, the metre and the purpose are also indicated. There are four Saṃhitās, Viz. the *Ṛgveda* or 'Book of Devotional Verse'; the *Yajurveda* or 'Book of sacrificial Formulae', the *Sāmaveda* or the 'Book of Psalms' and the *Atharvaveda* or the book of Mystico-therapeutic Priestcraft', It is to be noted that the pieces contained in these 'collections' are very much older than the time of their codification into the four *Saṃhitā*s, having been composed at different periods of times and having been current by oral tradition when the pieces were selected and arranged in a definitive order.

The *Ṛgveda* is the oldest and the most important of the *Saṃhitā*s. It comprises of 10,462 verses in 1028 hymns classified into 10 *maṇḍala*s according to the subject or the seer-families of the hymns. The *Yajurveda* is current in two traditions. The *Śukla* ('white'), available

in two recensions, is entirely in verse, divided into 40 chapters, and the *Kṛṣṇa* ('Black'), current in four recensions, contains a large number of theological and other discussions and explanations in prose, interspersed with verses. The *Sāmaveda* comprises of about 2000 verses, of which 1875 have been taken out of the *Ṛgveda* and the rest from elsewhere. It is arranged into four sections and set to music for being sung during sacrifices. The *Atharvaveda*, current in two recensions, contains about 6000 verses, put under 731 hymns, arranged into 20 sections. A Seventh of the hymns of the *Atharvaveda* are common to those of the *Ṛgveda* and the work is nearly as important in the matter of antiquity and contents as the *Ṛgveda* itself.

The *Brāhmaṇa*-s

Next in order are the several *Brāhmaṇa* texts allied to each of the Vedic *Saṃhitā*-s and dealing mainly with the sacrificial rites, the ritualistic application of select passages from the relevant Veda and speculation of the ideas underlying them. The important *Brāhmaṇa* texts are *Aitareya* and *Śāṅkhāyana* related to the *Ṛgveda*, the *Śatapatha* of the *Śukla Yajurveda*, *Taittirīya* of the *Kṛṣṇa-Yajurveda* and *Gopatha* of the *Atharvaveda*. The *Brāhmaṇa*-s are important for an understanding of the social, mythological and scientific thought- currents prevalent during the Vedic age.

The *Āraṇyakas and Upaniṣad*-s

The *Āraṇyaka* texts allied to the different *Saṃhitās* are concerned with the exposition of the symbolical significance of sacrificial ceremonies, and the *Upaniṣads* concern themselves with philosophical speculations and the expositions of the ways and means for the attainment of the highest value of life. Of the *Āraṇyakas*, the *Aitareya* and *Śāṅkhāyana* are related to the *Ṛgveda* and the *Taittirīya* to the *Kṛṣṇa-Yajurveda*. About 250 *Upaniṣads* are current, but only about a score of them belong to the Vedic age, the rest being later, aligning themselves to different schools of Philosophy and later religious cults. There is not much information of astronomical significance in the *Āraṇyakas* and *Upaniṣads*.

The *Vedāṅgas* (Ancillary Vedic texts)

While the Vedic *Saṃhitās* set out the basic hymns and the *Brāhmaṇas* the sacrifices in which they are used, another set of texts called the *Vedāṅgas* helped in a proper understanding, interpretation and application of the hymns. Of the six *Vedāṅga*-s, *Śikṣā* concerned itself with phonetic, *Vyākaraṇa* with grammar, *Chandas* with metre, *Nirukta* with etymology, *Kalpa* with performances of rituals and Jyotiṣa with astronomy. Two of the six *Vedāṅga*-s are of significance to the history of astronomy first, *Kalpa*, which consists of practical manuals on the performance of Vedic sacrifices and household rituals, contain sections called *Śulba-sūtras* which, among other things, mention methods of orientation and make use of geometry, irrational numbers and other mathematical ideas in the construction of sacrificial altars. The other is the *Vedāṅga Jyotiṣa*, 'ancillary Vedic astronomy', of which three texts are available, related respectively, to the *Ṛgveda*, *Yajurveda* and the *Atharvaveda*. The first two containing, respectively 36 and 43 verses, are ascribed to the same author *Lagadha*. Their basic content is almost the same, the latter having some additional matter, and from manuals for computing the civil calendar and proper times for the performance of rituals. The work locates the summer solstice in the middle of the constellation *Āśleṣā* and winter solstice at the beginning of *Dhaniṣṭhā*, calculating backwards from the present position of the solstices; this would give a date *c.*1370 B.C. The *Atharva Jyotiṣa*, which is in the form of a dialogue between *Pitāmaha* and sage *Kāśyapa*, in 162 verses, is astrological in content. Mention might be made here also another work related to the *Atharvaveda*, Viz. the *Nakṣatra-kalpa*, which enumerates 28 constellations from *Kṛttikā*, indicates their presiding deities, their groupings according to the part of the day and the directions and rituals pertaining to them; the work is thus astrological in content.

Nature of Astronomical content in Vedic texts

Though the Vedic poets did not compose the hymns for setting out scientific information, these extensive texts contain pertinent

indication of the concepts and practices relating to the astronomy of the times. Especially significant in this regard are the cosmological hymns of the *Ṛgveda* and the *Atharvaveda.* Moreover, the recording, in some of the hymns, of celestial observations enables one to compute back within margins, the date of composition of those hymns.

The lunar year was followed and the Moon was called *māsa-kṛt* 'maker of months.'[4] A full cycle of seasons delimited the year and the beginning of the year was ascertained by the proximity of a bright star to the full-moon which is clearly visible to the naked eye. Such stars recorded in different hymns of the *Ṛgveda* as the harbingers of autumn or the autumnal equinox are *Aditi* (*Punarvasu,* Pollux, long. 113°), *Dakṣa* (*Abhijit, Vega,* long. 284°), *Rudra* (*Ārdrā*, Betelguese, long. 88°), and *Rohiṇī* (Aedebaran, long. 69°). This change has obviously been the result of the precession of the equinoxes. Calculating at the rate of 72 years per degree, with due allowance for error, the periods referred to should, respectively, be *c.* 6200 B. C., 5400 B. C., 4350 B. C. and 3070 B. C. which should be the dates when the respective hymns were composed. A process of intercalation had also been in vogue for the correlations of the lunar year with the year of the seasons.[5]

The Ṛgvedic hymn I. 164, on the cosmic times - wheel by sage Dīrghatamas, speaks of a wheel of time, with a year consisting of twelve lunar months and 360 lunar days (*RV.* I.164.1) and starts the year with the autumn star *Agni* (*Kṛttikā*, Alcyon, long 59.5°) which on calculation gives a date c. 2350 B.C. In another Ṛgvedic hymn 3. 99, which also mentions *Kṛttikā* as the autumn star (*c.* 2350 B.C.), sage Viśvāmitra worships 3339 (371x9) *devas* and apparently refers to a period of 30 years consisting of 371 lunar months. This would give a year of 371 lunar days, working out to 365. 19 solar days.[6] Incidentally, it may be noticed that in the above cited hymns (*RV* I.164 and 3. 99), the numbers used (12, 360; 371, 3339, 33 and 11) have been expressed in the decimal system. Attention might also be drawn to the *Yajurveda*[7] enumerating multiples of 10 up to thirteen digits with specific names for each.[8]

While some of the stars are mentioned in the *Ṛgveda*, the *Yajurveda* and the *Atharvaveda* give full lists of the 27 (or 28) stars commencing from *Kṛttikā*. A fair knowledge of calendrical science is apparent in the full treatment of *gavām ayana* and other sacrifices of different durations based on the daily progress of the Sun. The equinoxes and solstices were determined accurately.[9] The twelve lunar months are named and so also the intercalary months. For ritualistic purposes the day-time had severally been divided into two, three, four, five, and fifteen equal parts, each division having a different nomenclature. Of the five planets mentioned only Jupiter (*Bṛhaspati*) and Venus (*Vena*) are referred to by name.[10] The solar eclipse[11] is described as the occultation of the Sun by *Svarbhānu* (*Rāhu*). P. C. Sen Gupta has determined the date of a total eclipse of the sun described in the *Ṛgveda* (5. 40.4-9) as 3928 B. C.[12] It is interesting to note that the *Taittirīya Brāhmaṇa* (3.10.9) extols *nakṣatra-vidyā* ('science of stars') and mentions a hierarchy of scholars who cultivated the science.[13] Professional astronomers were termed *nakṣatra-darśa* 'star-gazer'.[14] and *gaṇaka* 'calculator'.[15]

JAINA LITERATURE

Canonical literature

The Jains displayed extensive literary activity from early times and their canonical literature contain information on a wide range of subjects, religious, philosophical, social and scientific. The original texts, termed *Pūrvas*, are said to have lost and the *Śvetāmbara* sect of Jains had them recast later in the *Ardha-māgadhī Prākṛta* from exciting fragments and oral tradition. Their basic canonical texts number 45 (or 50), besides a large number of subsidiary texts. The basic texts are classified as *Aṅgas, Upāṅgas, Prakīrṇakas, Chedasūtras* and *Mūlasūtras.*

The *Aṅgas* are twelve in number and deal with doctrinal matters, rituals, legends and the like. They are the *Ācārāṅga, Sūtrakṛtāṅga, Sthānāṅga, Samavāyāṅga, Bhagavatī or Vyākhyāprajñāpti, Jñātṛdharmakathā, Upāsakadaśā, Antakṛddaśā,*

Anuttara-aupapātikadaśā, Praśnavyākaraṇa, Vipākasūtra and *Dṛṣṭivāda*. Of these, *Sthānāṅga* and *Bhagavatīsūtra* contain information on mathematics and astronomy.

There are twelve *Upāṅgas* corresponding to the *Aṅgas*, but not directly related to them. These are: *Aupapātika, Rājapraśnīya, Jīvājīvābhigama, Prajñāpanā, Sūryaprajñapti, Jambūdvīpaprajñapti, Candraprajñapti, Nirṇayāvalī, Kalpāvataṃsikā, Puṣpikā, Puṣpacūlikā* and *Vṛṣṇidaśāḥ*. Among these, Jaina cosmogony is dealt with in *Jīvājīvabhigama* and *Jambūdvīpaprajñapti* and details of Jaina astronomy are to be found in *Sūryaprajñapti* and *Candraprajñapti* and also in *Jambūdvīpaprajñapti*.

The third set of texts called *Prakīrṇakas*, 'Miscellaneous texts' are ten in number and like the *Pariśiṣṭas* (ancillary texts) of the *Vedas*, treat of numerous matters related to the canon. One of these texts, the *Taṇḍulavaitālika* contains, among other things, measures of length and of time.

There are nine *Chedasūtras* which deal with the rules of conduct and life of monks and nuns, monastic jurisprudence and edificatory legends.

Extensive and highly important from the point of contents are the four *Mūlasūtras*, viz. *Uttarādhyayana, Āvaśyaka, Daśavaikālika* and *Piṇḍa-niryukti*, of which the first one contains occasional passages relating to mathematics and astronomy.

Two individual texts called *Cūlikāsūtras* of an encyclopaedic nature, the *Nandisūtra* and *Anuyogadvārasūtra*, sometimes included in the *Prakīrṇakas*, make up the *Śvetāmbara* canon. These texts deal with numerous topics, including topics on astronomy and mathematics, which a Jaina monk was supposed to know.

Chronology of Jaina canon

Jaina tradition holds that the canon taught by Mahāvīra Jina was dutifully handed down for six generations and, when it tended to lapse into oblivion, a Council was called at Pāṭalīputra where 12 *Aṅgas*

were resuscitated. When it was again thrown into disorder, another Council was held at Vallabhi in the 6th Century A.D. and it was again reconstructed. Detailed analysis of the contents and language of the canon as it exists would show that the most ancient portions took shape during the third and fourth century B. C.

The Jaina canonical texts are highly repetitive and numerous passages are common to different texts. The several topics dealt with in the Jaina canons were later classified by Āryarakṣita (by Samantabhadra according to some) and arranged into four collections entitled *Caraṇānuyoga, Dharmakathānuyoga* (or *Prathamānuyoga*), *Gaṇitānuyoga* (or *Karaṇānuyoga*) and *Dravyānuyoga*. Matters relating to astronomy, mathematics, geography and allied subjects have been collected in the *Gaṇitānuyoga*.

The Jaina canons speak of astronomy as an important branch of study and as essential equipment for a Jaina priest for computing the correct time for religious performances. The *Sūryaprajñapti*, *Candraprajñapti* and *Jambūdvīpaprajñapti*, give a full depiction of the astronomical concepts and practices of the Jainas. The first two texts are entirely devoted to the subject, while the third, which is an extensive work divided into seven sections, devotes its last section for astronomy; it also enumerates, in section two, forty five divisions of time commencing from *asaṅkhyāta* being 'inscrutable infinitesimal time', to *śīrṣaprahelikā*, which is equal to several crores of years. The astronomical material contained in all these three works is almost the same in essence.

Extensive expositions are also available for the above works. For the *Sūryaprajñapti* there is commentary by the versatile Jaina scholastic Malayagiri (c. 1100-1200 A. D.) and a *Nirukti* by Bhadrabāhu, latter is known only through quotations. *Candraprajñapti* too has been commented on by Malayagiri, for the *Jambūdvīpaprajñapti*, Malayagiri's commentary is known only through quotations, but a detailed commentary by Śānticandra (16th Cent. A.D.) is available. Padmanandin, an author of *c.* 1000 A. D. has abridged the work in his *Jambūdvīpaprajñapti-saṅgraha*.

Post-canonical Jaina Literature

Post-cononical Jaina literature is very voluminous and encompasses all disciplines. A brief mention might be made here of the more important writings relating to astronomy.

The *Tattvārthādhigama-sūtra* of Umāsvāti (A.D. 185-219) contains a section on cosmology, which deals with astronomy as well. Commentaries on this work are available by Umāsvāti himself and by later scholars. The *Trilokaprjñapti* by Yativṛṣabha (between A. D. 473 0and 609) is an encyclopedic work in 7000 verses and in its chapter seven; there is a long extract on astronomy. It is noteworthy that the treatment of the subject here exhibits considerable parallelisms in thought and expression with the *Āryabhaṭīya*[16]. *Jyotiṣakaraṇḍaka*, possibly by an early author by name Pādaliptācārya, is based on the *Sūryaprajñapti* and contains the entire gamut of Jaina astronomy. The work has been commented on by Malayagiri who quotes earlier commentaries also. The *Karaṇānuyoga* or *Gaṇitānuyoga* of the *Digambara* sect of Jainas is again a compilation of astronomical and mathematical material scattered in the different Jaina texts, including *Sūrya* and *Candraprajñapti* and *Jayadhavalā*.

Among later Jaina works on astronomy the under mentioned are noteworthy: *Jyotissāra* by Thakker Pheru (14th cent.) in 238 verses, divided into four chapters; *Dinaśuddhi* by Ratnaśekhara Sūri (15th cent.) in 144 verses for computing the true Sun, Moon etc., *Maṇḍalaprakaraṇa* by Vinayakuśala in 99 verses, composed in A. D. 1596, with an elaborate commentary, *Jyotiḥprakāra* by Jñānabhūṣaṇa (*c*. A. D. 1700) in seven sections, and *Chandrārkī* by Dinakara (16th cent.) on the computation of true Sun and Moon and its commentary by Kṛpāvijaya.

A few works on astronomical instruments produced by Jaina astronomers under Muslim inspiration are also known. These include *Yantrarāja* by Mahendra Sūri (A.D. 1348) who was a courtier of Sultan Feroz Shah Tughlaq, and its commentary by Malayendu Sūri and *Ustaralaya-yantra* by Meghalaya (*c*. A. D. 1500) in the construction and use of astrolabes, with a commentary by the author himself. Among

manuals on astronomy by Jaina authors, a mention might be made of *Karaṇarāja* in ten sections by Muni Sundara (c. A. D. 1600). A number of *Pañcāṅga* manuals for the computations of the daily calendar are also known to be composed by later Jaina scholars.

ASTRONOMICAL *SIDDHĀNTAS*

Nature of the Siddhāntas

The few centuries immediately preceding and following the Christian era are of significance in the history of Indian astronomy in spite of the fact that practically no important work on astronomy of the times has come down to us intact, but for the Jaina texts mentioned earlier. The reasons are not far to seek. This was a period when the Vedic age evolved into the classical age at the advent of Buddhism and Jainism and the direct contact with the Greeks and the Romans. The unorthodox bent of thought and new sources of knowledge should have had their impact upon the intellectual endeavors of the Vedic Indians, resulting in novel strides in all walks of life including the pursuit of sciences. In the discipline of astronomy, this period witnessed the advent of a class of texts called *Siddhāntas*, characterized by a better scientific approach and more comprehensive treatment. The *Siddhānta* astronomy adopted more sophisticated mathematics, incorporated the planets in the system, and devised a system that coordinates for the determination of the periods of planetary revolutions and of the relative size of the Earth, the Sun and the Moon. The *Nakṣatra* system was dispensed with and replaced by the twelve signs of the zodiac. The mean longitudes were calculated from the number of days elapsed from the beginning of long periods of time called *Kalpa* or the *Kaliyuga*. The length of the year and day-lengths were correctly determined. Planetary positions were computed using eccentrics and epicycles. The eclipses were computed with greater accuracy by correcting the results for parallax. Computations were characterized also by geometrical, arithmetical and algebraic practices, some aspects of plane and spherical trigonometry, and the application of indeterminate equations.

Early *Siddhāntas*

According to tradition, there existed 18 early *Siddhāntas* composed by Sūrya, Pitāmaha, Vyāsa, Vasiṣṭha, Atri, Parāśara, Kāśyapa, Nārada, Garga, Marīci, Manu, Aṅgiras, Lomaśa (Romaka), Pauliśa, Cyavana, Yavana, Bhṛgu and Śaunaka. Most of these have gone out of vogue and lost, but five are available in the form of summaries or, what is more likely, extracts, in the *Pañcasiddhāntikā* of the prolific writer of astrology Varāhamihira (A.D. 578), being the *siddhāntas* of Pitāmaha, Vasiṣṭha, Pauliśa, Romaka and Sūrya. Another *Sūryasiddhānta* is available in modified form, which became very popular later. The reason for the disappearance of the early *siddhāntas* is to be sought in their super cession by later *siddhāntas* characterised by greater accuracy, easier methods of calculation and comprehensiveness. The non-availability of the early *siddhāntas* in their full and original form makes it difficult to reconstruct the development of the discipline during this period.

Later *Siddhānta*-s

The later *Siddhānta*-s followed, in the main, the general pattern of the earlier *siddhāntas,* but there was substantial development in the matters covered, the range of data used and the manner in which the subject was set out. For various reasons, the schools represented by the different *siddhāntas* came to be popular in different parts of the country, where texts in extension, expositions, systems of computation, practical manuals (*karaṇas*) astronomical tables (*koṣṭhakas*), descriptions of instruments (*yantra*) and other miscellaneous writings, came to be composed, mainly in Sanskrit, and also in the different provincial languages.

The *Āryabhaṭīya* of Āryabhaṭa I (b. A. D. 476) is the earliest of the later *siddhāntas*. In 121 verses, divided into four chapters, it sets out: Ch. I. The astronomical constants and the sine table; II. Mathematics required for computations; III. Division of time and rules for computing the longitudes of planets using eccentrics and epicycles; and IV. The armillary sphere, rules relating to problems of trigonometry and the

computation of eclipses. The *Āryabhaṭīya* started a new school of astronomy which grew popular in South India and threw up extensive literature, both expository and original in nature.

The *Āryabhaṭīya*, the parameters and other astronomical elements of which constituted *Āryapakṣa*, had its epoch at sunrise at Laṅkā, at the commencement of the *Kaliyuga*, on Friday, 18 February 3102 B.C. Āryabhaṭa wrote still another work, apparently entitled *Āryabhaṭasiddhānta,* which had its epoch at midnight 17/18 February 3102 B.C. and formed the basis for the *Ārdharātrikapakṣa* in Indian astronomy. The text of this work is not available now, but is known through quotations and a summary of its tenets mentioned in later works[17].

The earliest available commentary on the *Āryabhaṭīya* is by Bhāskara I, who wrote from Vallabhi in Gujarat (A. D. 629), but he names earlier exponents of the school like Lāṭadeva and Pāṇḍuraṅgasvāmī. Other scholiasts of the *Āryabhaṭīya* include Someśvara (11th -12th Cent.), also from Gujarat, and several from South India, including Sūryadeva Yajvan (b. 1191), Parameśvara (*c.* 1450), Yallaya (1480), Nīlakaṇṭha Somayāji (b. 1444), Raghunātha Rājā (1597), Ghaṭīgopa, (*c.* 1800) and Bhūtaviṣṇu. Bhāskara I wrote also two authoritative works on the system of Āryabhaṭa, the *Mahābhāskarīya* and *Laghubhāskarīya*, in eight chapters each. These texts too have been elaborately commented upon, the former by Govindasvāmin (c. 800-850) with a super commentary by Parameśvara, Sūryadeva Yajvan, Parameśvara and in *Prayogaracanā* by an anonymous author. The *Laghubhāskarīya* has been commented by Śaṅkaranārāyaṇa (A. D. 869), Udayadivākara (A. D. 1073) and Parameśvara.

The *Brahma-sphuṭa-siddhānta* of Brahmagupta (b. 598) exerted great influence in the astronomical thought of western and northern India as works based on it would show. In 1008 (or 1022) verses divided into 24 (or 25) chapters, it expounds the *Brahmapakṣa* and criticizes the *Āryapakṣa* of Āryabhaṭa. Chapters 11 and 22 are important for the reason that in the former he criticizes the view of some of his predecessors, including Āryabhaṭa, Pradyumna, Lāṭadeva, Varāhamihira, Vijayanandin, Viṣṇucandra's *Vāsiṣṭha-siddhānta,*

Śrīṣeṇa's *Romaka-siddhānta* and the Jainas and in the latter gives details of astronomical instruments, Pṛthūdakasvāmin (c. 860) wrote an erudite commentary on the work, in which he quotes an earlier commentary by Balabhadra. Other commentators of *Brahma-sphuṭa-siddhānta* are Āmarāja, Bhaṭṭotpala, Lalla, Someśvara, Śrīdatta and Varuṇa. This *siddhānta* was taken to Baghdad where it was translated into Arabic under the title, *Al-Zij-al-Sindhind* in A. D. 771 or 773 by Muhammad ibn Ibrahim al-Fazārī[18].

A Later *Pauliśa-siddhānta*, which adopts the parameters of the *Ārdharātrikapakṣa* but makes major improvisations otherwise is known from citations occurring in the works of Pṛthūdakasvāmin, Bhaṭṭotpala, Āmarāja and Al-Bīrūṇī[19].

The *Śiṣyadhīvṛddhida-tantra* of Lalla (8th -9th cent.) in 12 chapters, is based on the *Ārdharātrikapakṣa* of Āryabhaṭa, but incorporates *bīja*-corrections and makes certain improvisations from the *Brahmasphuṭa-siddhānta*. It contains an informative chapter on astronomical instruments and has been commented upon by Bhāskara II (b. 1114) and by Mallikārjuna Sūri (12th cent.).

The later *Sūryasiddhānta*, a comprehensive work in 12 chapters, has been highly popular throughout India. It adopts the *Ārdharātrikapakṣa* but makes modifications. Among its large number of commentaries might be mentioned those of Mallikārjuna Sūri (12th cent.), in Telugu and Sanskrit, Caṇḍeśvara (12th cent.), Madanapāla (14 cent.), Parameśvara (1432), Yallaya (1472), Rāmakṛṣṇa Ārādhya (1472), Bhūdhara (1572), Tamma Yajvan (1599), Raṅganātha (1603), Nṛsiṃha (1611), Viśvanātha (1628), Kamalākara (17th cent.) and Dādābhāi[20] (18th cent.).

The *Vaṭeśvara-siddānta* by Vaṭeśvara (A. D. 904) follows the *Āryapakṣa* and *Saurapakṣa* and gives a thorough treatment of astronomy in three sections. A point of interest in the work is that, as an ardent admirer of Āryabhaṭa, Vaṭeśvara vehemently criticizes Brahmagupta and refutes his views in ch. 10 of sn. I of the work.

Śrīpati's *Siddhāntaśekhara* (A.D. 999) which in 20 chapters follows the *Brahmapakṣa*, is important, in that it gives rules for determining the moon's second inequality and evection. An incomplete commentary on the work by Makkibhaṭṭa is available in print.

The *Siddhānta-śiromaṇi* (A. D. 1150) of Bhāskara II, who hailed from the Karnataka region, is by far the most comprehensive *siddhānta* work in Indian astronomy. It is based on *Brahmapakṣa*. The work is in four parts: I. *Līlāvatī* on arithmetic, II. *Bījagaṇita* on algebra and III. *Gaṇitādhyāya* and IV. *Golādhyāya* on astronomy. The epicycle-eccentric theories are fully developed to account for planetary motions. The section on astronomical instruments is also more full than earlier treatises. The four parts of the work have also been studied and are independent of each other. All these have been supplied elucidative glosses called *Vāsanā-bhāṣya* by the author himself. About 50 other commentaries are known for *Līlāvatī* and the other parts also have been commented upon by several scholiasts. The more important commentaries on *Gaṇitādhyāya* and *Golādhyāya*, which form the astronomical components of the work, are by Lakṣmīdāsa (A. D. 1501), Gaṇeśa Daivajña (17th cent.), Nṛsiṃha (1621) and Munīśvara (17th cent.).

In his short work *Siddhānta-darpaṇa*, Nīlakaṇṭha Somayāji (*b*. 1444) sets out the astronomical constants according to the *Āryapakṣa* as corrected by him and also the situation of the armillary sphere. He has also commented on this work in detail. His *Tantrasaṅgraha* in 432 verses, divided into eight chapters, however gives a full treatment of the subject.

A few *siddhāntas*, apocryphal in nature, are available in print. They are: *Vṛddhavāsiṣṭha-siddhānta* in 13 chapters dealing with all topics of astronomy, *Vāsiṣṭha-siddhānta*, in 95 verses divided into five chapters, *Soma-siddhānta* a comprehensive work in ten chapters, and *Brahma-siddhānta* in 764 verses divided into six chapters which claims to be a part of *Śākalya-saṃhitā*. There is also a *Vyāsa-siddhānta*, in three sections entitled *Bhuvanakośa*, *Kakṣādhyāya* and *Golādhyāya*, which claims to be part of *Vyāsasmṛti*.

Mention might be made here of a late *siddhānta* work entitled *Siddhānta-sundara* by Jñānarāja who wrote from Pārthapura on the Godāvarī in A.D. 1503. The author claims that Brahmā, Sūrya, Soma, Vasiṣṭha and Pulastya agree with his *Saurapakṣa* parameters. It is again to be noted that by Brahmā he refers to the *Brahma-siddhānta* of the *Śākalya-saṃhitā* noticed above. The work has a commentary by the author's son Cintāmaṇi (*c*. 1530).

Karaṇas

Astronomical computations based on *kalpas* and *yugas* involving large numbers being cumbersome, a genre of practical manuals, called *karaṇas*, arose and was designed to lighten the work of calculations and produce quick and more accurate results. A contemporary date at the sunrise of which there occurred a conjunction of the moon and its higher apsis, was chosen, as the epoch[21] and the longitude of the other planets were determined accurately for this moment to be used as zero corrections. Computations were then made with this epoch as the basis. Usually *bīja* corrections were also applied to the parameters.

The recensions of the *Pauliśa* and *Romaka-siddhāntas* of Lāṭadeva (6th cent.) pupil of Āryabhaṭa, redacted in the *Pañcasiddhāntikā* of Varāhamihira (d. 587) are the earliest *Karaṇa* texts in Indian astronomy. The *Sūrya-siddhānta* of the *Pañcasiddhāntikā* is also a *karaṇa* text, and according to Al-Bīrūnī this is also a work of Lāṭadeva. The epoch of all these *karaṇas* is 21 March, 505. It is interesting to note that chapter 4 of his *Pañcasiddhāntikā*, dealing with spherical trigonometry is called *Karaṇādhyāya*. Obviously, at that time, the term *karaṇa* meant only 'astronomical calculations' and *siddhāntas* included also *karaṇas*.

The *Khaṇḍakhādyaka* of Brahmagupta, of epoch 23 march 665, bases itself on the *Ārdharātrikapakṣa* of Āryabhaṭa I. The different astronomical topics are dealt with in nine chapters, which form Pt. I of the work. In Pt. II corrections are given to the parameters of part I, changing them to *Brahmapakṣa*. The work had been extremely popular

in the whole of North India. It has been commented upon by Pṛthūdakasvāmin (A. D. 864), Bhaṭṭotpala (966A.D.), Āmarāja (c. 1200), Yamaṭa, Varuṇa and Śrīdatta. A *Khaṇḍakhādyaka-sāraṇī* is also known.

Laghumānasa of Muñjāla (10th cent.) is a *karaṇa* text in six chapters using the elements both of the *Āryapakṣa* and *Ārdharātrikapakṣa* and mentions of the second inequality in lunar motion. The work has been commented by Praśastadhara of Kashmir (A. D. 958), Sūryadeva Yajvan of the Cola countray (1248), Parameśvara (1409) of Kerala and Yallaya (1482) from the Telugu country. Muñjāla had composed also a *Bṛhanmānasa*, which is lost and is known only from quotations which give its epoch as 9 March 932; the epoch of the *Laghumānasa* is likely to be the same.

Rājamṛgāṅka of king Bhoja of Dhārā, whose epoch is 21 February 1042 is not available in its original form, but only in three incomplete versions, of which one version by Rāma is available in print.

The *Karaṇaprakāśa* of Brahmadeva is based on the *Āryapakṣa*, and has its epoch on 11 March 1092. This *karaṇa* has been a popular work in south and west India and has commentaries on it by Dāmodara, Amareśa, Govinda, Śrinivāsa Yajvan and Sampatkumāra. Commentator Dāmodara has composed on his own, two *karaṇa* texts, *Āryatulya* in 1417, based on *Āryapakṣa* and *Sūryatulya* based on the *Sūrya-Siddhānta*.

The *Bhāsvati* of Śatānanda of Puri, Orissa, in 8 sections, is a popular *karaṇa* based on the *Sūrya-siddhānta* of Varāhamihira's *Pañcasiddhāntikā*. It follows the *Ārdharātrikapakṣa* and has been commented on by nearly 25 scholiasts.

Bhāskara II has written also an erudite *Karaṇakutūhala*, called also *Grahāgamakutūhala* and *Brahmatulya*. This work has been very popular in the west and north-west of India. It has its epoch on 23 February 1183 and follows the *Brahmapakṣa*. Of its several commentaries the more important are those by Ekanātha (1370),

Padmanābha (*c.* 1400), by Viśvanātha (1612) and by the Jaina astronomer Sumatiharṣagaṇi (1621). There is also a set of planetary tables based on this work, called *Brahmatulyasāraṇī*.

The *Grahalāghava* or *Siddhāta-rahasya* of the prolific astronomer Gaṇeśa Daivajña in 16 chapters, of each 18 March 1520, is very popular *karaṇa* commented upon by the author himself and by a host of scholiasts. Several planetary table based on *Grahalāghava* are also known.

Rāma-vinoda by Rāma a courtier of Akbar, belongs to the *Saurapakṣa* and has 11 March 1590 for its epoch. The author himself prepared a *Koṣṭhaka* for the work, while there is a commentary on it by Viśvanātha (1602). Still another *karaṇa* following the same *pakṣa* is the *Sūryapakṣaśaraṇa* or *Khacarāgama* of Viṣṇu, having the epoch 7 March 1608, on which Viśvanātha wrote a commentary in 1612.

Koṣṭhaka-s or *Sāraṇi*-s

Alongside these *karaṇas* from about 10[th] cent., a genre of ancillary Tables called *koṣṭhakas* or *sāraṇis* come into vogue, in which were charted in columns, the planetary positions cusps of the astrological places or other calenderical functions like *tithis, nakṣatras, yogaṣ* etc. Since these tables were extremely handy for almanac makers, a very large number of *koṣṭhakas* or *sāraṇis* came to be produced, based on different *karaṇas*. In some cases authors of the *karaṇas* themselves prepared the *sāraṇis*. Every almanac-maker, priest and astrologer had to have his own copy of a *sāraṇi*, with the result that a very large number of manuscripts of this type of works is known.[22]

Diverse texts from Kerala[23]

Astronomical thought in South India, especially in Kerala, developed, from early times, certain features varying from the traditions in the rest of India. For this reason, It would be advantageous to assess, under a separate heading, the contribution of this region in the said aspects. It might be noted at the outset that Kerala had been a strong bastion of the Āryabhaṭan school of astronomy from early times.

Numerals in Keralite works are expressed in the *Kaṭapayādi* notation, and while the language of most of these works is Sanskrit, their commentaries are mostly in local Malayalam language.

i. *Parahita* and *Dṛk* system of computation.

Tradition has it that astronomers of Kerala gathered at Tirunāvāy on the Arabian coast in A.D. 683 and formally inaugurated the *Parahita* system of astronomical computation with emendations to Āryabhaṭan elements which had till then been followed in the land. The *Grahacāranibandhana* and *Mahāmārganibandhana* of Haridatta formed the basic texts of the system. Several centuries later, when results derived from *Parahita* were found not to tally with observation, Parameśvara(1360-1455) enunciated in 1431 his *Dṛk* system of computation through his *Dṛggaṇita*. While these two basic texts provided only the basic elements and rules, in their wake, a large volume of *karaṇa* literature, treating in detail some or all the topics of astronomy and introducing further changes novel methodologies and the like, came to be produced. Shortly after Haridatta, but apparently unconnected with his work, Devācārya wrote in A.D. 689 his *Karaṇaratna*, a full fledged *karaṇa*, dealing, in eight chapters with all the major topic of practical astronomy, including the determination of the longitudes of Sun, Moon and planets, the eclipses, gnomon shadow, rising of the Moon, heliacal visibility and planetary conjunctions. Among later texts might be mentioned the *Vākyakaraṇa* (*c*. 1300) to be noticed below, the *Dṛkkaraṇa* in 10 chapters of Jyeṣṭhadeva (1500-1610), *Karaṇasāra* of Śaṅkara Vāriyar (1500-60) in 4 chs. with auto-commentary, *Karaṇāmṛta* of Citrabhānu (1530) in 4 chs. having two commentaries, *Karaṇottama* of Acyuta Piṣāraṭi (1550-1621) in 5 chs. with auto-commentary, *Bhadradīpagaṇita* of Iṭakramañceri Nampūtiri (17th cent.), *Karaṇapaddhati* of Putumana Somayāji (1660-1740), *Jyotiśśāstrasaṅgraha* and *Saṅgrahasādhanakriyā* of Āḷvāñceri Tamprākkaḷ (18th cent.) and *Sadratnamālā* of Śaṅkara Varman (1800-38). There are at least eleven different texts with the common title *Pañcabodha*, some of them with commentaries, nine texts with the title *Grahagaṇita*, two text with the title *Kriyāsaṅgraha*, a dozen texts

with the title *Vyatīpātagaṇita* and several other anonymous texts, often with commentaries.

ii. Astronomical *Vākyas*:

The *Parahita* and *Dṛk*-based systems make use of a large number of mnemonics couched in the form of words, phrases or short sentences (*vākyas*) which, when deciphered in terms of the *kaṭapayādi* system of numeral notation, yield different astronomical tables. These *vākya*-mnemonics relate to all sorts of astronomical tables, to wit, the 248 daily longitudes of the Moon for 9 anomalistic months (well-known as the *Candravākyas* of Vararuci) 3031 daily lunar longitudes for 110 anomalistic months, 2075 *vākyas* called *Samudra-vākyas, Maṇḍala-vākyas* or *Kujādipañcagraha-mahāvākyas* for the five planets, 570 for *Kuja*, 528 for *Budha*, 231 for *Guru*, 165 for *Bhṛgu* and 551 for *Śani*, the different sines of arc (*jyās*), deductive components to be used in computations and so on and so forth. Some of the *Karaṇa* texts make profuse use of these mnemonic-*vākyas*. Following Haridatta's basic *Parahita* manual *Grahacāranibandhana*, the first known major text that makes use of this device is the *vākya-karaṇa* (*karaṇa* utilizing *vākyas*) in five chapters, apocryphocally attributed to Vararuci but composed about A. D. 1300. The work has been commented upon in great detail by Sundararāja (*c.* 1500) of Viprasadgrāma near Trichinapally in Tamilnadu. The almanac-makers of the Tamil region of South India fully make use of the *Vākyakaraṇa* for computing their almanacs, which, therefore, are known as *Vākya-pañcāṅgas.*

iii. *Tantra* texts:

Alongside the *karaṇa* texts, which were more in the nature of practical manuals, a genre of texts which aimed to be more comprehensive in the treatment of the topics, besides serving the purpose of the *karaṇas*, came to be produced. These texts followed the *Āryapakṣa*, retained the beginning of *Kali*, viz. 18 Feb., 3102 B.C., as the epoch, and expressed numbers in the *bhūtasaṅkhyā* notation

instead of the *kaṭapayādi* notation of the *karaṇas*. To this genre belong the *Vārṣikatantra* of Viddaṇa, son of Mallaya (before 1370), in 11 chapters, the *Tantrasaṅgraha* of the versatile astronomer Nīlakaṇṭha Somayāji (*b*. 1444), *Sphuṭanirṇaya-tantra* of Acyuta Piṣāraṭi (1550-1621) and the *Tantrasāra* of Nārāyaṇa of the Perumanam village in central Kerala. The last has been commented in Malayalam, but for the second, there are five commentaries including the elaborate *Yuktidīpikā* of Śaṅkara which takes pain to explain the rationale of the theories and the computations.

iv. *Veṇvāroha* texts :

Mādhava of Saṅgamagrāma near Cochin (*c*. 1360-1425), whose investigations into the value of π and other trigonometrical functions, differential in sines of arc etc. are well known, has devised an ingenious method to determine, at intervals of 2 hours and 40 minutes each, every day, the longitude of the Moon correct to the second, utilizing the cyclic nature of the 248 lunar *vākyas* equal to nine anomalistic months. On a parallelism between this method and the knots in a bamboo tree, he called this *Veṇvāroha* method. For use in this computation, Mādhava also refined the lunar *vākyas* correct to the second. The *Veṇvāroha* method has been set out in two of his works, the *Sphuṭacandrāpti* and *Veṇvāroha*. The ingenuity of this method appealed to other astronomers also and we have several works of the type, including a *Dṛg- veṇvārohakriyā* of epoch 1695, and Putumana Somayāji's *Veṇvārohāṣṭaka*.

v. Planetary tables :

Besides his work on the moon, Mādhava has worked on Planetary motions as well and has determined the longitudes of the planets for long cycles of years and the results have been set out in the form of tables in his *Agaṇita-grahacāra*. Two other anonymous works of a similar nature are also known, both under the common name *Grahacāra*, one of them for the years 1845-55.

vi. Eclipses:

Investigations on accurate computation of eclipses had the greatest appeal to Kerala astronomers, perhaps, next only to the computation of the planets. This is exemplified also by the series of observations of eclipses made and recorded by astronomers like Parameśvara and Nīlakaṇṭha. A large number of works on eclipse computation, short or long, some of them improvising new or revised elements and methodologies, are known. Among these might be mentioned: The *Grahaṇāṣṭaka* and *Grahaṇamaṇḍana* (epoch 15 July 1411) of Parameśvara, *Grahaṇanirṇaya* of Nīlakaṇṭha (b. 1444), an *Uparāgakriyākrama* based on Nīlakaṇṭha's work, another *Uparāgakriyākrama* by Nārāyaṇa (1561), *Uparāgaviṃśati* and *Uparāgakriyākrama* by Acyuta Piṣārati (1550-1621), and *Grahaṇagaṇita* and *Grahaṇāṣṭaka* by Putumana Somayāji (1660-1740). A number of anonymous works on the subject are known: Two short texts under the name *Grahaṇāṣṭaka* III-IV, another under the title *Uparāgāṣṭaka* (epoch 1563) a *Grahaṇopadeśa*, three texts under the general title *Grahaṇādigaṇita* and then under the title *Grahaṇagaṇita*. Some of these texts have also commentaries mostly in Malayalam.

vii. Computation of the Shadow :

Still another genre of texts relate to the computation of the Moon's shadow towards determining the time and therefrom planetary positions. Of this genre of works, the under mentioned are important: *Candracchāyāgaṇita* I of Parameśvara, *Candracchāyāgaṇita* II with a detailed commentary by Nīlakaṇṭha, two more *Chandracchāyāgaṇitas* (III-IV), which remain anonymous, and *Chāyāṣṭaka* of Acyuta Piṣārati. Other works on the subject, all anonymous, are *Candra-cchāyā-nayanopāya*, four different tracts of the title *Chāyāgaṇita*, *Sūryacandracchāyāgaṇita* and two works called *Sūryacchāyādigaṇita*.

viii. Astronomical rationale:

One of the major hurdles in the history of Indian astronomy lies in the tendency of the early scientists to record the results only of their findings

and fail to record, similarly, the steps that led to those results. Apart from this tendency, it was necessitated also by the fact that the results had to be recorded in as succinct a manner as possible, in the form of aphorisms or verses. An understanding of the mental working of the scientists is thus lost for posterity. This defect has been remedied to a great extent; so far as mathematics and astronomy are concerned, through a class of writings called *yukti*-s (rationale). Many of these are short anonymous tracts dealing with individual items, processes or formulae and are found written on flyleaves or ends of manuscripts of astronomical works. From among full-fledged works of this class might be mentioned; the *Lagnaprakaraṇa* of Mādhava (1360-1440) on the computation of the ascendant, the *Grahaṇanyāyadīpikā* of Parameśvara on eclipse computation, *Yuktibhāṣā* of Jyeṣṭhadeva (1500-1610), an extensive work in two parts, depicting the rationales of arithmatic, algebra, geometry and trigonometry in the first part and the astronomy in the second, *Rāśigolasphuṭānīti,* according to Acyuta Piṣāraṭi, giving the rationale, at length, for measuring planetary longitudes on the ecliptic, and *Nyāyaratna* of Putumana Somayāji. A fairly long tract explains the rationale of the Āryabhaṭan verses *Kakṣyāpratimaṇḍala* etc.(*Abh kāla* 17-21). A number of minor tracts on astronomical rationale have been put together in a collection called *Gaṇitayuktayaḥ.* Among Keralite commentaries which afford expository rationale might be mentioned, the *Yuktidīpikā* on Nīlakaṇṭha's *Tantrasaṅgraha* and *Kriyākramakarī* on Bhāskara's *Līlāvatī,* both by Śaṅkara (1500-60), and Acyuta Piṣāraṭi's commentary on his own *Karaṇottama.*

ix. Observation and experimentation :

A unique work in Indian astronomy is the *Jyotirmīmāṃsā* of Nīlakaṇṭha, written in 1504, wherein he stresses the importance of astronomical observation, defends the necessity of correcting parameters periodically, on the basis of observation of eclipses, of the Sun, Moon and the planets, comparing the elements of different schools etc. Perhaps, more important is his *Grahaparīkṣākrama* wherein he demonstrates some of the astronomical methods.

Yantras : Astronomical instruments

Śaṅkaranārāyaṇa (A. D. 869), court-astronomer of King Ravi Varma of Kerala, refers, in his *Laghubhāskarīya-vyākhyā* (3. 20), to an observatory in the capital city, fitted with astronomical instruments, but gives no description thereof. While the gnomon *(śaṅku), nāḍikā* (water clock) etc. find mention in the *Śulbasūtras* and the Jaina text, a sustained description of astronomical instruments occurs, possibly, for the first time in *Āryabhaṭasiddhānta* of Āryabhaṭa I (*c.* 476). This work of Āryabhaṭa which sets out his *ārdharātrika pakṣa* is not available, but extracts from it are preserved in later works. Thus Rāmakṛṣṇa Ārādhya (A. D. 1472), while commenting on the *Yantrādhyāya* of the *Sūryasiddhānta* (ch. 13) quotes 34 verses on astronomical instruments from the *Āryabhaṭasiddhānata*.[24] Some of these verses are quoted and explained also by other commentators on the *Sūryasiddhānta* like Mallikārjuna Sūri (A. D. 1178) on verse 7. 12, and Tamma Yajvā (A. D. 1599) on vv. 13. 20-25[25]. Ch. 14 of Varāhamihira's *Pañcasiddhāntikā*, in 29 verses, is devoted to the subject of astronomical instruments, observations etc. Other early and medieval texts which mention the use of or deal with astronomical instruments are: *Mahābhāskarīya* ch. 3 esp. vv. 56-60 and *Laghubhāskarīya*, ch. 3 of Bhāskara I (A. D. 629), ch. 22 of *Brahma-sphuṭa-siddhānta* of Brahmagupta (b. 598), ch. 21 of *Śiṣyadhīvṛddhida-tantra* of Lalla (8th cent.), Ch. 13 of the *Sūrya-siddhānta* (c. 800), *Golādhyāya* of *Vaṭeśvara-siddhānta* (904) ch. 11 of Pt. II. of the *Siddhānta-śekhara* of Śrīpati (c. 1050) and ch. 19 of the *Siddhānta-śiromaṇi* of Bhāskara II (1150).

The works on astronomical instruments written later generally bearing the impress of Central Asian astronomy were brought to India by the Muslims, which will be noticed in the next section. There are, however, a few which treat only of Hindu instruments, mostly written in Gujarat or Rajasthan. Among these might be mentioned the following: The *Yantraratnāvalī* of Padmanābha (c. 1400), with a commentary by the author himself. The second chapter of this work, called *Dhruvabhramaṇādhikāra* describes an instrument for ascertaining the

exact time at night from the position of the pole star. Cakradhara, son of Varuṇa wrote a short work entitled *Yantracintāmaṇi* of which four commentaries are available, one by the author himself and the others by Hariśaṅkara, Paramasukha and Rāma Daivajña (1625).[26] The prolific Gaṇeśa Daivajña, son of Keśava Daivajña of Nandigrāma (1507), wrote a work on instruments entitled *Cābukayantra* or *Pratodayantra*. An extensive work on the subject is the *Yantraprakāśa* of Rāmacandra with auto commentary which describes as many as 27 instruments, including a *Kācaghaṭiyantra*. *Yantrarājavicāraviṃśādhyāyī* of Nayanasukhopādhyāya also finds mention here.[27] The texts of this genre are short and a close reading of the commentaries are always necessary to get a full idea of the form, nature and use of the instruments of the Hindu period.

ARABIC AND PERSIAN SOURCES:

While the people of India and Iran belonged to the same Aryan stock and their religion, literature and culture had close relationship from very early times, it was only from the eighth century that scientific exchanges between India and central and west Asia took positive shape largely due to the rise of Islam. The reign of the second Abbāsid Caliph al-Mansūr (A. D. 753-74) heralded an era when considerable Indian scientific literature, especially on medicine and mathematics including astronomy, were redacted into Arabic. The services of Indian scholars who had mastered Arabic helped in this exchange and among Arabic scholars, the names of Ibrāhim al Fazārī (d. 796 or 806), Ya'qūb ibn Ṭāriq, al-Khwārizmī (d. c. 850), al-Kindī (d. c. 873), Habash al-Hāṣib (d. c. 864 or 874) are noteworthy. Many of these Arabic translations are lost, but the details thereof are preserved in the *Fihrist* or 'Index' of Abu'l Faraj Mahammad of Baghdad, better known as Abi Yā'qūb an-Nadim (A. D. 988). Details about scholars of science and their contributions occur in Sn. II of the *Fihrist*.

Al-Birūnī

A potential source of information about Indian and Perso-Arabic literature on astronomy and allied disciplines is the large quantum of writings left by Abdu'l-Raiḥān Al-Bīrūnī (973-1050) who accompanied

Sultan Maḥmūd of Ghazni during his campaigns and stayed in north-west India for the best part of 1017-30. A versatile scholar of Persian and Arabic, and also of Sanskrit, Al-Bīrūnī, wrote 135 works comprising of Studies, collections and translations, of which as many as 27 pertain to Indian culture, philosophies and sciences.[28] His work entitled *Kitāb ft taḥqiq mā lil-Hind min maqālatin maqbūlatin fi 'l-aql au mardhūla* ('Verifications of what is said about India which is accepted or rejected by reason') *Ta 'riq al-Hind,* in short translated into English under a title *Al-Bīrūnī's India* by Edward Sachau, is well known for the comprehensive information it supplies on contemporary India.[29] Valuable information of Indian astronomy and mathematics is contained in his undermentioned works: *Jawamī al Maujūd li-Khawghṭir al Hanūd fi Ḥisāb al-Tanjim* (collection of the ideas of the Indians on astronomical Calculatios'),[30] Al-Jawābāt "*an al-masāil al wārida min munajjim*' l-Hind ('Replies to questions raised by Indian astronomers'), *Al-Qānūn al Mas 'ūdi* (Book on Astronomy).[31] It is worth noting that Al-Bīrūnī endeavored to transmit to Western Asia the knowledge contained in Sanskrit astronomical texts through translations into Arabic or Persian. Such texts included Brahmagupta's *Brahmasphuṭa-siddhānta* and *Khaṇḍakhādyaka*, *Pauliśa-siddhānta*, Varāhamihira's *Laghujātaka* and *Bṛhatsaṃhitā* and *Karaṇatilaka* of Vijayanandin. The worth of Al-Bīrūnī's writings lies in the fact that, apart from the intrinsic value of their contents, they provide new information, corroborative evidence and help in the identification and dating of authors, works and views.

Encyclopaedias

Another authentic source of contemporary information is the *Ā 'in-i-Akbari*, the Imperial Gazetteer of the times of the Mughal emperor Akbar, prepared by his minister Abu'l-Faḍl (1551-1602). The work carries details on a variety of subjects, including an account of Indian and Arabic astronomy.

The influx of scholars from the Middle East to India and the patronage extended to them by Muslim rulers, not only in Delhi but also in the provinces, resulted in the production of a number of encyclopedic works containing, among other things substantial

information of astronomy in its several aspects.[32] Among them the following deserve mention for the wealth of details contained therein: *Jawāharu 'l-Ulūmi-Humāyūn* composed by M. Fādil b. Ali B. M. al-Miskīnī al-Qaḍi Samarqandī of the court of the Mughal emperor Humayun in 1555.[33], *Uqūl-I Asharh* M. Barārī Ummī b. Jamshīd (A. D. 1673),[34] and *Shahid-Ṣādiq* by Ṣādiq B. M. Ṣāliḥ al Isfahānī-al-Azadānī (A. D. 1646) of the court of emperor Shahjehana.[35]

Zīj (Astronomical tables)

The genre of astronomical tables indicating planetary positions, star charts and conversion tables with notes and explanations, on line with the famous *Zij-i Ulugh Beg* and *Zīj-i Khāqāni* of Samarqand came to be produced, generally under state patronage,[36] like *Zīj-i Nāsiri* (13th cent.) by Maḥmud b. 'Umar dedicated to sultan Iltutmish[37] (1246-65), *Zīj-i Fāmi* (1448-61) by Maḥmūd Shāh Khaljī[38] and *Zīj-i Shahjaḥani*[39] by Faridu'd-din Mas'ud b. Hafiz Ibrahim Manajjm, Court astronomer of emperor Shahjehan (1628-58). More important, however, is the highly elaborate *Zīj-i Muḥammad Shāhi*[40] (1727) prepared by Sawai Jaisingh (1686-1743), dedicated to the Mughal emperor Muhammad Shah (1719-48). Divided into three sections, the work gives rules for the transformation of four calendars, measurement of time in 19 chapters, and motions of stars and planets and their position from a certain longitude, latitude etc. in five chapters. That this work was later revised as *Zīj-i Fadid Muḥammad Shāhī* (New Astronomical tables of Muḥammad Shāhī) in four chapters would indicate how matters were developed further. It is interesting to note a Sanskrit version of this *Zīj* had also been prepared for the use of Hindu astronomers. The Arabic and Persian Zījes studied and produced in India will be further discussed in chapter 2.

Mingling of Traditions

In the wake of introduction of Arabic and Persian astronomical tradition into India under State patronage, there arose an effort, on the part of Hindu astronomers, to produce translations, adaptations and books of a combined tradition, the combination taking mostly the form

of mere addition, explanation of one through the other, or regular coalescence. Obviously, such activities too were encouraged and patronized by the State. Such study required bilingual dictionaries. Thus Kṛṣṇadāsa, a protege of Akbar compiled a *Pārasiprakāśa* in about 1575, containing a Persian-Sanskrit dictionary of astronomical terms and a grammar of Persian in Sanskrit. Since this was inadequate for translators, Mālajit, who was honoured by Shahjehan with the title *Vedāṅgarāya*, wrote another *Pārasiprakāśa* in 1643, which gave classified lists of astronomical terms in Arabic and Persian with Sanskrit equivalents. Vrajabhūṣaṇa, son of Raghunātha, wrote in 1660 still another work of this nature entitled *Pārasivinoda* or *Pārasivinodānanda.*

In line with translating of Sanskrit texts into Arabic and Persian by Al-Bīrūnī and earlier in Baghdad[41], there had also been sustained efforts to translate Arabic and Persian texts into Sanskrit. These texts included those belonging to the school of Marāgha and Samarqand, like the *Zīj* of Ulugh Beg in *Fi ca Ulugbegi*, and al-Qushiji's *Risalah dar hay'at* in *Hayatagrantha*. In this vein, under the patronage of Sawai Jai Singh, Jagannātha Paṇḍita produced *Rekhāgaṇita*, being a rendering of Euclid's *Elements of Geometry* from its Arabic version *Tahirir-u-Uqlidas* by Naṣīr-ud-din aṭ-Ṭūsī (1201) and *Siddhānta-sārakaustubha* in 13 chapters being a rendering of Ptolemy's *Almagest* from its Arabic Version, also by Naṣīr-ud-din. It is worth noting here that, as against what is presumed by scholars all along, Jagannātha's *Samrāṭ-siddhānta* is really the title of an original work of the author, in five chapters, all along called *Yantrādhyāya*, and printed in continuation of the first 13 chapters, and these 13 chapters alone form the translation of the *Almagest* under the title *Siddhāntasārakaustubha*.[42] Nayana-sukhopādhyāya produced, under Jai Singh's inspiration, the *Ukarā*, being a Sanskrit rendering of the Greek work *Sphaerica* of Theodosius from its Arabic rendering by Qusta bin Luqa (912 A. D.). Nayanasukhopādhyāya translated into Sanskrit also of another work *Sharah-Tazkarah Barjandi.* [43]

As instances of incorporating Western ideas into India might be cited the *Siddhāntasārvabhauma* of Munīśvara (b. 1603), court

astronomer of Shahjehan (1628-59), and Kamalākara who wrote the *Siddhāntatattvaviveka* in 1658. These astronomers composed their works in the Hindu pattern, but used therein elements of Aristotelian physics, Euclidean geometry, Islamic trigonometry and Ptolemaic astronomy as found in *Ulug Beg*. Among works which tried to coalesce the two traditions might be mentioned in *Siddhāntasindhu* (1628) and the *Siddhāntarāja* (1639) of Nityānanda, astronomer in the court of Shahjehan, which adopted the Islamic parameters and the *Sāyana* year in computation. These innovations, however, remained confined to intellectual experimentations and did not permeate into general use among the people.

Astrolabes and Observatories

With Arabic astronomy came the astrolabe (Arabic *aṣṭurlab*, Sanskritized into ustaralava), a handy and versatile metallic instrument, which, through the manipulation of graduated discs and circles and of a gnomon attached to it, enabled one to ascertain planetary positions, the time of the day and the like. Being a complicated precision instrument, it was used to be prepared by hereditary families of experts with graduations and words inscribed in Persian script. As the instrument grew popular in the land, it began to be inscribed in *Devanāgarī* script, as well. Short works in Sanskrit also came to be composed describing the construction and use of astrolabes. The earliest work on the astrolabe is the *Yantrarāja* (1370), mentioned earlier based on Arabic sources, by Jaina Mahendrasūri, court astronomer of Frozeshah Tughlaq, in five chapters entitled *Gaṇita, Ghaṭanā, Yantraracanā, Yantraśodhana* and *Vicāraṇā*. There are commentaries on the work by Malayendusūri and Gopīrāja.

Other works on the subject, of a later period, include those of Malayendu (with Cintāmaṇi's commentary) and by Mathurānātha and some anonymous, but by far the most important is the *Yantrarājaracanā* by the royal astronomer Sawai Jai Singh and its rendering into verse form by Śrīnātha under the title *Yantraprabhā*, over which its modern editor Kedaranatha has added his own commentary, *Yantrarājaprabhā*.

A number of Indian astrolabes, of different types, combinations and functions are preserved in museums and other repositories and await detailed study.[44]

The efforts of the Rājā Sawāi Jai Singh of Jaipur (1686-1743) towards the fostering of scientific observational practices with the combined use of Hindu, Muslim and European advances in astronomy are a saga in itself in the history of Indian astronomy. Jai Singh collected texts of all the three traditions studied them himself and composed works, invited scholars of all the traditions and induced them to prepare original works and translations. He also invented and caused to be constructed instruments for astronomical observations. A manuscript entitled *Yantraprakāra*, preserved in the Art Gallery as No. 31 of the Mahārājā's Museum at Jaipur, mentions the under mentioned instruments as designed by Jai Singh with the caption: *Śrī-mahārājādhirāja-viracita-yantrāṇi*: (1) *Jayaprakāśa-yantra*, (2) *Nāḍīvalaya,* (3) *Krāntivṛtta*, (4) *Palabhāyantra*, (5) *Digaṃśayantra*, (6) *Śarayantra*, (7) *Agrayantra*, (8) *Yāmyottaramiti*, (9) *Jatulahalaka*, (10) *Yantrarāja* (astrolabe, mentioned above), (11) *Jātuśukavataina*, (12) *Sudasphakarī*, (13) *Jātuśukataina*, (14) *Śaṅkuyantra* and (15) *Pratirāśinām krāntivṛttāni*.[45] The main features and methods of observation of some of these instruments have been indicated by Jagannātha in the first chapter of his *Samrāṭ-siddhānta*.

Three instruments, viz. *Jayaprakāśayantra, Rāmayantra* and *Samrāṭ-yantra* are stated to have been invented by him. Realising, by experience, that these metallic insruments suffered from limitations on account of their smallness, wear and tear, and the effect of weather, he constructed massi outdoor observatories, like those of Ulug Beg in Samarqand, in Delhi (1724), Jaipur (1734), Ujjain (1734) Varanasi (1737) and at Mathura on the Yamunā. Massive models of several of the instruments were also installed by him at these observatories[46]. The contribution made by Jai singh and that inspired by him from a potential source for the study of a special phase of the history of Indian astronomy.

NOTES AND REFERENCES:

1. For a succinct and fully documented analysis of the archaeology of ancient India, see S. N. Sen, p. in *A Concise History of Science in India*, 1-15.
2. See Marshall (1); Vats; Mackey (1), (2).
3. For the astronomical interpretation of seal 2430, see Bag, (3).
4. *ṚV* 1. 105. 18, as explained in Yāska's *Nirukta* 5.4.20.1; see also Roy, S. B. (1), 1-4.
5. Roy, S. B. (1), 14-35.
6. Roy, S. B. (1), 118-37
7. *YV (Śukla),*17.2. ff.; *YV (Kṛṣṇa),* 4.4.11.4; 7.2.20.1.
8. For a documentation of Vedic references to numbers in the decimal system, see Macdonell and Keith, *Vedic index under Dasan*, (Vol. I. 342-44).
9. See *YV (Kṛṣṇa),* 7.4.8: *Kauś, Br*, 19.3; *Tāṇḍ Br*, 5.9; Sen Gupta, P. C. (b). article *Solistices in Vedic Literature*, 155-74).
10. *ṚV*. 4. 50.4; 10.23.1.
11. *ṚV.* 1. 105.10.
12. *The solar eclipse in the Ṛgveda and the date of Atri*, in Sen Gupta P. C. (6) 101-31.
13. For a documentation of Vedic Astronomy, see Sarma K. V. (7), 1-20.
14. *YV. (Śukla)* 3. 10, *Tait. Br.* 3. 4. 4.
15. *YV. (Śukla)* 30. 20, *Tait. Br.* 3. 4. 15.
16. Jain, L. C., 137-46; also see Ed. K. V. Sarma with Tr. Intro., Notes, Madras, 1993.
17. Shukla, K. S., (3) 83-105; *Glimpses from the Āryabhaṭasiddhānta*, *Indian Journal of History of Science*, 12. 194-99, 1977.
18. Pingree (9), 103-23.
19. Pingree (8) 172-241.
20. Pingree (14), 23-24.
21. On the advantage of accruing from the derivation of such an epoch, see Sarma, K. V. Introductions to his editions of the *Sphuṭacandrāpti* and *Veṇvāroha* of Mādhava.
22. For a documented account of these texts see Pingree, (14) 41-46.

23. For detailed and documented survey of the field and the works noticed in this section see Sarma K. V. (5), Pingree, (14), 47-51. See also, Sarma K. V., *Science Texts in Sanskrit in the Mss. Repositories of Kerala and Tamilnadu,* Rastriya Sanskrit Sansthan, New Delhi, 2002.
24. For a discussion on these verses, see Shukla (3), 83-105.
25. Sukla (9), 181-85.
26. Middleton, 831-40.
27. Pub. Ed.by V.B. Bhattacharya, *Sarasvatī Bhavana Granthamālā,* 115, Varanasi, 1979.
28. See Khan, Ahmad Saeed, *A Bibliography of the Works of Abu 'l-Raihan-Al-Bīrūnī.*
29. Khan, *ibid*, G. 1. No. 93.
30. Khan, *ibid*, G. 1. No. 5.
31. Khan, *ibid*, G. 1. No. 104.
32. Rahman, 599-613.
33. Rahman, 607.
34. Rahman, 607.
35. Rahman, 608.
36. Rahman, 377-78.
37. Rahman, 330.
38. Rahman, 330.
39. Rahman, 306-07.
40. Rahman, 348-49.
41. Gupta, 219-36.
42. Sharma M. L., 244-51.
43. Bahura, G. N., 58. For other translations, see Bag, (2) 79-93.
44. See Kaye (1), (2) Behari and Govind, Govind.
45. Bahura, G. N., 57.
46. See Kaye (1) and (2) Hunter (3). Sharma, Shakti Dhara Singh, Prahlad.

INDIAN ASTRONOMY IN THE VEDIC AGE*

The Beginnings:

The origins of astronomy in India have to be traced to the intelligent interest that the brilliant starlit sky and the heavenly bodies had excited in the Vedic seer in the dim past, and the assiduous observations with which he followed the recurring natural phenomena, like day and night, the seasons, the phases of the moon, the transit of the heavenly bodies, the eclipses, etc. From the fourth millennium B. C. or earlier, when the *Vedas,* which are the most ancient Indian literature, began to be composed, several astronomical observations came to be recorded, some significant astronomical speculations broached upon and some generalizations attempted. Such professionalists as *Nakṣatra-darśa* 'star gazer'[1] and *Gaṇaka* 'calculator'[2] who practiced the *Nakṣatra-vidyā* 'science of the stars'[3] came into being in due course.

Pre-scientific and Scientific Astronomy

The development of astronomical science in India could advantageously be studied under two heads, viz., Pre-scientific astronomy and scientific astronomy. Scientific astronomy might be said to have commenced when the fundamentals of science have been established and strict rules and procedures of computation, have been formalized. The system could then grow on a rational basis. In the history of Indian astronomy, the scientific period could be said to have started towards c. A. D. 500, with Āryabhaṭa (born A. D. 476), from when on, there has been a long line of recorded astronomical tradition reaching down to the 17th century in general and right up to the 19th century in remote corners of India like Kerala[4]. This period of nearly one and a half millennia, produced several lines of astronomers, who maintained the tradition and also made substantial original contributions, some of which were rediscovered, much later, in modern astronomy.[5]

**Vivekānanda Kendra Patrikā,* Feb. 1983.

The attainment of the scientific stage, however, necessarily presupposes an era of observation and speculation, extending over a long period of time. During this period, queries would have been raised and explanations offered, theories would have been propounded, verified and revised, rules would have been formulated and tried, and procedures would have been devised and short cuts sought for. This empirical stage in the evolution of the discipline in India, might be termed the pre-scientific period of Indian astronomy.

Sources of the Pre-scientific age

Chronologically, this period in Indian astronomy, should be taken to commence from when the Vedic hymns began to be composed towards ç. 4000 B. C. and to have lasted till 500 A. D. when, as indicated before, scientific astronomy emerged.* Subsequently the extensive elucidatory literature thereon, called the *Brāhmaṇas,* and supplementary texts thereto, called *Āraṇyakas;* the philosophic expositions called *Upaniṣads;* and the six *Vedāṅgas,* composed with the purpose of inculcating the correct method of recitation and right way of understanding the Vedic texts, and setting out the exact performance and punctual observance of the Vedic rituals were composed. Two of these six *Vedāṅgas,* viz., *Jyotiṣa* and *Kalpa,* the latter in its last section called *Śulba,* are of particular importance in the study of the growth of astronomy in India. The former, viz., *Vedāṅga-jyotiṣa*, being short texts attached to the *Ṛgveda, Yajurveda* and the *Atharvaveda,* sets out certain definitive aspects of Vedic astronomy while the latter viz., the *Śulbasūtras,* being mensuration manuals for the construction of different types of fire altars, and compiled by Bodhāyana, Āpastamba, Kātyāyana, Mānava, Maitrāyaṇīya, Varāha and Vādhūla, codify the practical side of Vedic astronomy. The two epics of India, viz., the *Mahābhārata* and the *Rāmāyaṇa*, which, too, belong to the pre-scientific age of Indian astronomy, contain several useful references, so also the earlier *Purāṇa* texts. The Jainas had a fervour for mathematics and in some of their canonical texts, is to be found a section named *Gaṇitānuyoga*, 'system of

*For more ref. see the article "*A Survey of Source materials*."

calculation'. Among the Jaina texts which contain mathematical and astronomical material, might be mentioned *Sūryaprajñapti, Jambudvīpaprajñapti, Sthānāṅgasūtra, Uttarādhyayana-sūtra, Bhagavatī-sūtra, Anuyogadvāra-sūtra* and the *Bhāṣya* by Umāsvāti on the *Tattvārthādhigama-sūtra**. Last to come in this period are the five systems of astronomy, viz., the *Paitāmaha-siddhānta, Vāsiṣṭha-siddhānta, Saura-siddhānta, Romaka-siddhānta* and the *Pauliṣa-siddhānta*, whose original texts are not available, but whose tenets have been set out by Varāhamihira in his *Pañcasiddhāntikā* (505 A. D.).

Vedic Period : Nature of the source material

While examining the literature of the period for side-lights on astronomy, it is necessary to keep in mind two factors. The *Vedas* are, primarily, religious texts, on prayer and worship. The subsidiary texts attached to them, like the *Brāhmaṇas, Āraṇyakas* and the *Upaniṣads*, are also primarily intended to explain and expostulate upon the text of the Vedic prayers and prescribe the rituals connected with worship. This would, naturally mean that the astronomical observations in these texts would only be incidental references and disconnected statements. The only consolation in the matter is that Vedic literature is very voluminous and contains such casual references, in sufficient measures as to enable the reconstruction of the astronomical knowledge attained in those days. It is also pertinent to mention, in this connection, that, as in other disciplines like medicine, the growth of the science of astronomy, was guided by contemporary religious and social utility. A purely theoretical approach to the discipline, as is often the case in modern times, was not the order of the day. This attitude would explain why, in many cases, the traditional mathematicians of India stopped short at certain stages and confined themselves to certain aspects of astronomical problems. It goes without saying that the above background is to be kept in view while making a proper appraisal of the evolution of astronomy in India. What is attempted here is to set out the noteworthy developments in Indian astronomy as could be ascertained directly or indirectly from the material available to us.

*For more ref. see the article "*A Survey of Source materials.*"

Evolution of science during the Vedic period

During the Vedic period, astronomy and mathematics developed side by side with the religious and cultural life of the Aryans. These disciplines, in a way, engendered, enhanced and stabilized their manifold ritualistic practices in regard to the performance of these rituals at the correct times, places and altars. In due course, these disciplines came to be two of the main props, sustaining and perpetuating the Vedic rituals. A fair idea of the stage reached in the growth of astronomy during this period, could be obtained by examining the concepts recorded therein, on various matters connected therewith.

Genesis of the Universe

According to Vedic speculations, existence came out of non-existence - *asataḥ sad ajāyata* (*ṚV.* 10.72.2). Several statements, sometimes fanciful, are strewn in Vedic literature on the origin of the universe, from among which one from the *Ṛgveda,* is worth being quoted:

> *ṛtam ca satyam cābhiddhāt tapaso 'dhyajāyata I*
> *tato rātry ajāyata tataḥ samudro arṇavaḥ II*
> *samudrād arṇavād adhi samvatsaro ajāyata I*
> *ahorātrāṇi vidadhad viśvasya bhiṣato vaśī I*
> *sūryacandramasau dhātā yathāpūrvam akalpayat I*
> *divam ca pṛthivīm cāntarīkṣam atho svaḥ II*
>
> (*ṚV.* 10. 190.1-3).

'Truth and truthfulness were born from intense penance. Hence was darkness born and thence the watery ocean.'

'From the watery ocean was born the year, ordaining days and nights, the controller of every living moment.'

'The creator then created, in due order, the sun, the moon, the sky, the earth and the regions of the air and light'.

Another conception mentioned in the *Taittirīya Upaniṣad,* is that 'From the Soul (*Ātman*), space arose; from space arose, air; from

air, fire; from fire, water; from water, the earth; from the earth, plant life; from plant-life, food; from food, man'.

Tasmād vā etasmād ātmanaḥ ākāśaḥ sambhūtaḥ; ākāśād vāyuḥ; vāyor agniḥ; agner āpaḥ; adbhyaḥ pṛthivī; pṛthivyā oṣadhayaḥ; oṣadhibhyo annam; annāt puruṣaḥ. (Taitt. Upa. 2.1).

Configuration of the Universe

Several concepts are in evidence in the *Vedas* about the configuration of the universe. Sometimes, the universe is supposed to be made up of the earth and the sky *(dyā vā pṛthivī)*, but more often, as in the famous *Puruṣa-sūkta* of the *Ṛgveda* (10.90), as consisting of three parts, viz. the earth, the atmosphere and the sky (*bhūmi, antarīkṣa and dyauḥ*):

nābhya āsīd antarīkṣam śīrṣṇo dyuḥ samavartatā I padbhyām bhūmiḥ....... (*ṚV.* 10.90.14)

On the relative positions of certain objects of nature, the *Taittirīya Saṃhitā* notes that fire rests on the earth, air in the atmosphere, sun in the sky and moon in the company of the constellations: *cf. yathāgniḥ pṛthivyā.........vāyave samanamad, ...vāyur antarikṣeṇa sūryāya......... sūryo divā candramase........., candramā nakṣatrair varuṇāya samanamat. (Tait. Sam.* 7.5.23*)*. On the relative position, particularly, of the sun and the moon, both of which shine in the sky and are described in the Ṛgvedic *mantra*; *suparṇā eta āsate madhya ārodhane divaḥ (ṚV.* 1.105.11) the Vedic exegetist Sāyaṇa, quoting earlier authorities, says that the moon is supposed to be in the atmosphere (*antarikṣa*), while the sun traverses the sky, higher up. The universe, again, is conceived as infinite in extent. A Vedic poet extolling the might of the great god Indra, equates it with the 'infinite' universe (*ṚV.* 1.52.11).

The Sun

The sun is conceived as the sole lord and light giver of the universe *Cf.*

ekaḥ sūryo viśvam anu prabhūtaḥ I ekaivoṣāḥ sarvam idam vibhāti I (*ṚV.* 8.58.2).

'The one sun is the lord of the universe; one dawn, it lights up all this'.

The sun is also conceived as the prime supporter and controller of the world. The *Ṛgveda* observes:

sūryasya cakṣū rajasaity āvṛtam tasmin arpitā bhuvanāni viśvā. (*ṚV.* 1.164.14).

'The sun's eye keeps revolving; on it depends all the worlds'.

Elsewhere it is stated: *mitro dādhāra pṛthivīm uta dyām,* (*Taitt. Sam.* 3.4.11).

'The sun supports the heaven and the earth'.

The sun is also said to control the seasons and cause the winds; cf. *ṛtūn praśāsad vi dadhāvanuṣṭhu* (*ṚV.* 1.95.3) and *pavamānaḥ pavate savitṛprasūto hy eṣa etat pavate (Aitareya Brāhmaṇa, 2.7).* In the *Ṛgveda,* it is stated that God Varuṇa charted in the sky a broad path for the sun, which, obviously, refers to the ecliptic:

urum hi rājā varuṇaś cakara, sūryāya panthāmanvātavā u (*ṚV.* 1.24.8).

'King Varuṇa has made a spacious pathway, a pathway for the sun to traverse'.

The ecliptic is divided into twelve segments and the theory of the 'twelve suns' (*dvādaśādityāḥ*), should have arisen from the sun moving through the twelve segments.

The Moon

The moon is spoken of in the *Vedas* as *sūryaraśmi* 'sun's light' i.e., one which shines by the sun's light; cf. *sūryaraśmiś candramā* (*Tait. Sam. 3.4.7.1),* but still it is as bright as the sun (*adhi tviṣīr adhita sūryasya*, *ṚV.* 9.71.9). It appears in new forms day after day (*navo navo bhavati jāyamānaḥ, ṚV.* 10.85.19) in its different phases. Some

of these phases have been given special names. That on the full moon day is called, *rākā* (*ṚV.* 2.32.4; 5.42.12) and that on the day previous to it, it is *anumati* (*Tait. Sam.* 1.8.8.1; 3.4.9.1). On the new moon day, it is called, *kuhu* (*Tait. Sam.* 1.8.8.1; 3.4.9.1; *AV.* 7.47) and on the day preceding it, it is called, *sinivālī*

(*Tait. Sam.* 1.8.8.1; 3.4.9.1; *AV.* 2.26.2; 7.11.3).

That the phenomenon of the new and full moon is related to the moon's elongation from the sun, has been correctly guessed. Thus, the invisibility of the moon on the new moon day, is explained figuratively by describing it to have been swallowed up by the sun and its appearance on the following day, by its being released by the sun. the *Śatapatha Brāhmaṇa* puts it allegorically as follows.

'*tad vā eṣa evendraḥ ya eṣa tapati, athaiṣa eva vṛtro yac candramāḥ, so 'syaiva bhrātṛvyajanmeva* I *tasmād yady api purā viduram ivodito 'thaināṃ etām rātrim upaiva nyāplabate, so 'sya vyāttam āpadyat* I *tām grasitvodeti* I *sa na purastān na paścād dadṛśe.........tam nirddhīya nirasyati* I *sa eṣa adhītaḥ paścād dadṛśe sa punar āpyāyate* I *sa etasyaivānnāddyāya punar āpyāyate*' I (*Śatapatha Brāhmaṇa* 1.5.4.18-20).

Now, (the sun) which burns there, is indeed, none other than Indra and the moon is none other than Vṛtra. But the former is hostile to the latter, and for this reason, though the moon, (Vṛtra) had previously risen at a great distance from him (the sun, Indra), now swims towards the latter and enters (into his open mouth).

'Having swallowed him, he (the sun), rises; and the other one (moon), is not to be seen either in the east or in the west. Having sucked him empty, he (the sun) throws him (the moon) out and the latter thus sucked out, is seen in the western sky and again increases, he again increases to serve that (sun) as food. In essence, the above passage sets out the moon's elongation from the sun and its true motion from the west to the east.

The Earth, spherical and self-supporting

There are specific statements in the *Vedas,* which indicate the conception of the earth as a sphere which remains suspended, unsupported, in space. The Ṛgvedic seer asks a question:

pṛcchāmi tvā param antam pṛthivyāḥ pṛcchāmi yatra bhuvanasya nābhiḥ (*ṚV.* 1.164.34.).

I ask thee, which is the centre of the earth; I ask thee, where is the center of the earth. And the answer is given:

iyaṃ vediḥ paro antaḥ pṛthivyā ayaṃ yañjo bhuvanasya nābhiḥ (*ṚV.* 1.164.35).

'This altar (and, for that matter, any point on the surface of the earth) is the center of the earth: this sacrifice (performed on the altar), is (again), the center of the earth. This is an observation, which could imply the spherical shape of the earth, when alone, any point on its surface could be its centre. The global shape of the earth is more specific in the following mantra:

cakrāṇāsaḥ parīṇaham pṛthivyā hiraṇyena maṇinā śumbhamānāḥ I *na hinvānāsas titirus ta indram pari spaśo adadhāt sūryeṇa* II (*ṚV.* 1.33.8).

'Even though they were flying round the earth's periphery and traversing with great speed, the messengers were not able to vanquish Indra. Thereupon, he covered them with sunlight'.

The rotundity of the earth is implied in still another Ṛgvedic verse, which speaks of gradual nightfall at different parts of the earth:

āprā rajāṃsi divyāni pārthivā ślokam devaḥ kṛṇute svāya dharmaṇe I *pra bāhū asrāk savitā savīmani niveśayan prasuvan naktubhir jagat* II (*ṚV.* 4.53.3).

'The brilliant sun has filled the regions of the heaven and earth with light. He awakens the hymn for his own strengthening. He has stretched out his rays, putting the world to sleep and awakening it by turns'.

Gradual nightfall in some parts of the earth and dawn in other parts, as the sun traverses its course, naturally implies the roundness of the earth and its being freely suspended unsupported in space for the sun to go right round it,

The *Śatapatha Brāhmaṇa* describes the earth explicitly as a sphere; *parimaṇḍala u va ayam lokaḥ* (7.1.1.37).

Cause of day and night

The above-said realistic concept of the shape of the earth has induced a realistic conception also of the cause of day and night. The *Aitareya Brāhmaṇa* gives a logical explanation of the phenomenon:

> *sa va eṣa na kadācanāstam eti nodeti / tam yad astam etīti manyante ahnā eva tadantam itvāthātmānam viparyasyate / rātrīṃ evvastāt kurute 'haḥ parastāt / atha yad enam prātarudet iti manyante rātrer eva tadantam itvāthātmānam viparyasyate ahar evāvā vastāt kurute rātrim parastāt / sa vā eṣa na kadācana nimnocati - - - -*
>
> (*Ait. Br.* 14.6).

'He (the sun) never sets or rises. When (men) think that he is setting, he is only turning round, after reaching the end of the day, and makes night here and day below. Then when (men) think he is rising in the morning, he is only turning round after reaching the end of the night, and makes day here and night below. Thus, he (the sun), never sets at all.'

Gopatha Brāhmaṇa of the *Atharvaveda* also speaks in a similar vein (2.4.10).

Units of Time: *Kalpa* and *Yuga*

Classical Indian astronomy makes use of various units of time, beginning with *Kalpa* and *Yuga* consisting of millions of years and reaching up to a fraction of a second. In the *Veda*s, however, the word *Kalpa* is never used in the sense of a unit of time. The word *yuga* is used in the sense of a long period of time, though there is no specific mention of its length. The words *Kṛta, Tretā, Dvāpara* and *Kali,* being

the four *yugas* mentioned in later astronomy, are used in the *Vedas* merely to indicate different grades, each inferior to the former. It would seem that the specific sense of time attributed to these terms and their making up the *catur-yuga* the four 'aeons' is a later development except for *Dvāpara* which is found used in the *Gopatha Brāhmaṇa* (1.1.28) as a unit of time.

The basic time unit of the Vedic period is the year (*samvatsara*) and the *yuga* consisting of five years. The names of the years are specifically mentioned in the *Taittirīya Brāhmaṇa* in the passage:

Samvatsaro 'si, parivatsaro 'si, idavatsaro 'si, iduvatsaro 'si, idvatsaro 'si (*Tait. Br.* 3.10.4). The *Ṛgveda* (7.103.7-8) mentions two of these year names and the *Yajurveda* contains all the names with minor variations (*VS.* 26.45; 30.16).

The Year and the Month

The *Vedas* generally used the terms *sama, vatsara,* and *hayana* to denote the year; the term *varṣa* which is most popular in later astronomy is conspicuous by its absence in the *Vedas.* Names of seasons like *Śarad* and *Hemanta* were also used to indicate the year. The year reckoned was solar but the month reckoned was lunar. The reason for this is not far to seek. It was easy to measure a month from full moon to full moon, while a solar month would have to be computed, for which the means were not available in those days. That the year reckoned was solar, is clear from such passages as:

veda māso dhṛtavrato dvādaśa prajāvataḥ vedā ya upajāyate /

'*Dhṛtavrata* knows the twelve months; he knows also the month that is created (i.e., added)', (*ṚV.* 1.25.8).

The added month, obviously referes to the intercalary month which is added to correlate the lunar months with the solar year.

The year was taken to consist of 360 days. The *Ṛgveda* mentions this in a picturesque manner:

dvādaśāram nahi taj jarāya varvarti cakram pari dyāmṛtasya I
ā putrā agne mithunāso atra sapta śatāni viṃśatiś ca tasthuḥ II
(*ṚV.* (1.164.11).

'The wheel (of time, formed with twelve spokes, revolves round the heavens, without wearingout. O Agni, On it are 720 sons (viz., days and nights)'. The *Aitareya Brāhmaṇa* (1.7.7) is more explicit when it says:

triṇi ca vai śatāni ṣaṣṭiś ca saṃvatsarasyāhāni tāvān saṃvatsaraḥ I.

sapta ca vai śatāni viṃśatiś ca samvatsarasya horātrayaḥ II

360 is the number of days in the year... 720 is the number of days and nights,

The twelve months of the year have been named in the *Taittirīya Saṃhitā*, which also gives the names of the intercalary month as *samsarpa* and that of the expunged month as *amhaspati* terms, which are used in later astronomy, as well:

madhuś ca mādhavaś ca śukraś ca śuciś ca nabhaś ca nabhasyaś ca I *īṣaś ca ūrjaś ca sahaś ca sahasyaś ca tapaś ca tapasyaś ca* I *upayāmagṛhīto 'si sam sarpo 'syamhaspatyāya tvā* II
(*Tait. Saṃ*. 1.4.14).

(O Somajuice !) you are taken in by the dish (*upayāma)*. You are *Madhu, Mādhava, Śukra, Śuci, Nabhas, Nabhasya, Iśa, Ūrja, Sahas, Sahasya, Tapas* and *Tapasya*. You are also *Saṃsarpa* and also the *Amhaspati*.

The twelve months are distributed among the six seasons thus:

madhuś ca mādhavaś ca vāsantikav ṛtū I *śukraś ca śuciś ca graiṣmav ṛtū* I *nabhaś ca nabhasyaś ca vārṣikav ṛtū* I *īśaś ca ūrjaś ca śardav ṛtū* I *sahaś ca sahasyaś ca haimantikav ṛtū* I *tapaś ca tapasyaś ca śaiśirirav ṛtū* I *(Tait. Sam.* 4.4.11*)*.

The intercalary month, whose mention has been made in the *Taittirīya Saṃhitā* passage quoted above (1.4.14), which according to

the *Vedāṅga-jyotiṣa*, is to be added at the end of the second and the fifth year of the five year *yuga*, is an ingenious solution offered by the Vedic astronomer to compensate for the shift of the seasons in correlating the solar year with the lunar month.

Year - long sacrifice:

It would be interesting to notice here, how the Vedic priestly class practiced a repetitive Soma-sacrifice, covering the whole year, which by the way, would also demonstrate how religious ritual and astronomy went hand in hand in the Vedic age. Now, in a *Soma* sacrifice, offerings called *savana*, have to be made thrice a day - a fact which has given the period between one sunrise and another the appellation *savana* day. The said daily soma sacrifice was called an *aha*. Six such *ahas* constituted a *ṣaḍaha*, five *ṣaḍaha*s a *māsa*, and twelve *māsa*s, a *saṃvatsara-satra*. This sacrifice, as might be seen, exactly measures out the Vedic year. *Cf. Kālamādhava* of Mādhavācārya:

savana-śabdo ahorātropalakṣakaḥ, somayāge savanatrayasya ahorātrasampādyatvāt | ahorātrasādhyaḥ ekaḥ somayāgo bedesvahaḥ-śabdenābhidhīyate | tādṛśānām aharviśeṣāṇām gaṇaḥ ṣaḍahaḥ | ṣaḍahena pañcakena eko māsaḥ sampadyate | tādṛśair dvādaśabhir māsaiḥ sādhyam saṃvatsarasatram.

The Day

The day is generally denoted in the *Veda* by the term *vāsara*. The variable nature of its length, at different parts of the year, finds expression in a prayer in the *Ṛgveda*.

Soma rājan pra ṇa āyūṃṣi tārī rahanīva sūryo vāsarāṇi |

Oh Somarāja! Prolong thou our lives just as the sun increases the length of the days! (*ṚV.* 8.48.7).

The need for giving individual names to items even in a long series, is apparent in a system handed down by rote. But the extent to which the Vedic astronomer has gone in this regard is exemplified by

the names given to the several day times and night times and parts thereof, as will be noticed below. The names of the fifteen day-times in the light half of the month, (*pūrvapakṣa)* are:

samjñānam vijñānam prajñānam jānadaṃ bhijānad I *saṅkalpamānam prakalpamānam upakalpamānam upakḷptam kḷptam I śreyo vasīya āyath sambhūtaṃ bhūtam* II (*Tait. Br.* 3.10.1.13).

The names of the fifteen nights of the same half month are:

darśā dṛṣṭā darśatā viśvarūpā sudarśanā I
āpyāyamānā pyāyamānā pyāyā sūnṛterā I
āpūryamāṇā pūryamāṇā pūrayantī pūrṇā paurṇamāsī II
(*Tait. Br.* 3.10. 1.3).

The list of the fifteen day-times of the dark half (*apara-pakṣa*) of the month is:

prastutam viṣṭutam saṃstutam kalyāṇam viśvarūpam I *śukram amṛtam tejasvi tejas samiddham* I *aruṇam bhānuman marīcimadabhitapat tapasvat* II (*Tait.Br.* 3.10. 1.5).

And the fifteen names of the nights of the same *pakṣa* are:

sutā sunvatī prasutā sūyamāṇā 'bhiṣūyamāṇā I *pītī prapā sampā tṛptis tarpayantī* I *kāntā kāmyā kāmajātā ''yuṣmatī kāmadughā* II (*Tait. Br.* 3.10.1.3).

Division of the day

Consonant with the requirements of ritualistic practices, the day-time, i.e., the period between sunrise and sunset, had severally been divided into two, three, four, five and fifteen equal parts. In the two-fold division, the parts were called, *pūrvāhna* and *aparāhna*; in the three fold division, *pūrvāhna*, *madhyāhna*, *aparāhna*, in the four fold divisions, *pūrvāhna*, *madhyāhna*, *aparāhna* and *sāyāhna* in the five fold division, *prātaḥ*, *saṃgava*, *madhyāhna*, *aparāhna* and *sāyāhna*. In the fifteen-fold division, each part was called a *muhūrta*, a term used in later astronomy as well. The nights were also similarly

divided into fifteen *muhūrtas.* The *Taittirīya Brāhmaṇa* provides us with the names used for the sixty *muhūrtas;* fifteen making up the day time of a day in the light half of the month, fifteen the day time of a day in the dark half, fifteen the nights in the light half and fifteen the nights of the dark half, as follows:

citraḥ ketuḥ prabhānābhānthsambhān I *jyotiṣmāns tejasvānātapans tapannabhitapan* I *rocano rocamānaś śobhanaś śobhamānaḥ kalyāṇaḥ* II (*Tai. Brā.* 3.10.1.1).

dātā pradātā nando modaḥ pramodaḥ I *āveśayan niveśayan thsaṃveśanasaṃśāntaśśāntaḥ* I *ābhavan prabhavan thsaṃbhavan thsambhūto bhūtaḥ* II (*Tai. Brā.* 3.10.1.2).

savitā prasavitā dīpto dīpayan dīpyamānaḥ I *jvalan jvalitā tapanvitapan thsantapan* I *rocano rocamānaḥ śumbhūś śumbhamāno vāmaḥ* II (*Tai. Brā.* 3.10.1.2).

abhiśāstā anumantā ' 'nando modaḥ pramodaḥ I āsādayan niṣādayan thsaṃsādanas samsannas sannaḥ I ābhūr vibhūr prabhūś śambhūr bhuvaḥ II (*Tai. Brā.* 3.10.1.3) *

Each *muhūrta* is, again divided into fifteen *prati-muhūrtas* whose names, in order are:

idānīm tadānīm etarhi kṣipram ajiram I āśur nimeṣaḥ phaṇo dravan atidravan I tvarams tvaramāṇa āśur āśīyāñjavaḥ II

(*Tait. Br.* 3.10.1.4)**

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* The initial words of these sets of names are given elsewhere in the *Brāhmana,* where it is also indicated that these are the *muhūrta* names; *atha yad āha citraḥ ketur dātā pradātā savitā prasavitā abhiśāstā ' numanteti I eṣa eva tat I eṣa hy eva te 'hno muhūrtaḥ I* (*Tait. Br.* 3.10.9.29).

** That these terms denote the divisions of the *muhūrta* is stated elsewhere in the text; *atha yadāha...idānīm tadānīm iti. eṣa eva tat. eṣa hy eva te muhūrtānām muhūrtāḥ* - (*Tait. Br.* 3.10.9.31).

The *Ayanas*

The Vedic observers have taken note of the apparent half-yearly southern and northern progresses of the sun, called in later astronomy as *Dakṣiṇāyana* and *Uttarāyaṇa*, respectively. The *Taittirīya Saṃhitā* notes:

tasmād ādityaḥ ṣaṇmāso dakṣiṇenaiti ṣaḍuttareṇa I

'Thus the sun moves southwards for six months and northwards for six months'. (*Tait. Sam. 6.5.3).* These progresses are referred to in the *Ṛgveda* (10.2.7;10.18.1; 10.98.11) and *Atharvaveda* (12.2.10) as *Pitṛyāṇa* and *Devayāna.*

The Equinoxes and the Solstices

The equinoctial day (*viṣuvat),* is referred to frequently in Vedic literature, in connection with the timing of sacrifices. Thus while describing the *ekaviṃśa* sacrifice, the *Aitareya Brāhmaṇa* observes:

ekaviṃśam etad ahar upayanti viṣuvantam madhye saṃvatsarasya I

'The *ekaviṃśa (*rite*),* is performed on the (equinox) day, occurring in the middle of the year'. (*Ait. Br.* 18.4).

The solstices find mention in connection with the performance of sacrifices. The *Kauṣītakī Brāhmaṇa* contains such a reference with an instructive procedure to fix the correct time of the solstice:

sa vai māghasyāmāvāsyāyām upavasati, udann avarisan I upeme vasanti, prayāṇīyendatirātreṇa yakṣyamānaḥ, tad enam prathamam āpnuvanti I tam caturviṃśenārabhante I tad-ārambhaṇīyasya ārambhaṇīyatvam I sa ṣaṇmāsān udanneti I tam ūrdhvaiḥ ṣaḍahair anuyanti I sa ṣaṇmāsān udann ītvā tiṣṭhate, dakṣiṇāvartsann upeme vasanti vaiṣuvati-yenāhna yakṣyamāṇaḥ I tad enam dvitīyam ānuvanti I sa ṣaṇmāsān dakṣiṇaiti I taṃ āvṛttaiḥ ṣaḍahair anuyānti I sa ṣaṇmāsān dakṣiṇetvā tiṣṭhate, udann avartsan I upeme mahāvratīyenāhna yakṣamānaḥ I tad enam tṛtīyam āpnuvanti I taṃ yat trittāpnuvanti tredhāvihito vai saṃvatsaraḥ,

saṃvatsarasyaivāptyai I tad utaisāpi yajñagāthā gīyate ahorātrāṇi vidadhād urna va iva dhīr yaḥ I ṣaṇmāsa dakṣiṇa nityaḥ sad udann eti sūryaḥ II

iti I ṣaḍ hy eṣa udan māsāneti ṣaḍ dakṣiṣa. tadvai na tasmin kāle dīkṣeta I Anāgatam sasyam bhavati I dah arakanyahani bhavati I samvepamana avabhriad udayanti I tasmād atra na dīkṣeran I caitra - syāmāvasyāyā ekaḥ uparistād dīkṣeran I āgatam sasyam bhavati I mahānty ahāni bhavanti I asamvepamāna avabhṛtād udayanti I tasmād etad sthitam II

This interesting passage may be rendered thus: 'On the new moon of *Maghā,* he (the sun), rests, being about to turn northwards. They (the priests), also rest, being about to sacrifice with the introductory *atirātra.* Thus, for the first time they (the priests), obtain him (the sun). On him they lay hold with the *caturviṃśa* rite, that is why *ārambhaṇīya* rite has that name, (meaning laying hold). He (the sun), goes north for six months; him they (the priests), follow with six-day sacrifices in continuation. Having gone for six months he (the sun), stands still, being about to turn southwards. They (the priests), also rest being about to sacrifice with the *viṣuvanta* day. Thus, for the second time, they get him (the sun). He goes south for six months. They follow him with six-day rites in the reverse order. Having gone south for six months he stands still, and they, about to sacrifice with the *mahāvrata* day, obtain him for the third time. In that they obtain him thrice, the year is in three ways arranged. Verily it serves to obtain the year. With regard to this, this sacrificial verse is sung:

Ordaining the days and nights like a cunning spider,
For six months south constantly, for six months the sun goeth.

For six months he goes north, six to south. They should not consecrate themselves at this time; the corn has not arrived, the days are short, shivering they come out from the final bath. Therefore, they should not consecrate themselves at this time. They should consecrate themselves one day after the new moon of *Caitra*; the corn has come, the days are long, not shivering they come out from the final bath.

Therefore, that is the rule. (*Kauṣītakī Brāhmaṇa,* 19.3). Another equally interesting reference to the solstice occurs in the *Taittirīya Saṃhitā* (7.4.8), where prescriptions are given for consecration for a year - long sacrifice beginning on the *Ekaṣṭaka* day, is described. The same rite is prescribed also in the *Tāṇḍya Brāhmaṇa* (5.9.). [6]

Precession of the Equinoxes

An understanding of the equinoxes and the solstices and the practice followed in fixing the beginning of the year, should have, naturally, led the Vedic astronomer to an apprehension of the precession of the equinoxes. This is apparent in his shifting the beginning of the year from one constellation to another. Thus the *Śatapatha Brāhmaṇa* notes that the *Phalguni nakṣatra,* indicated the beginning of the year;

cf. eṣa ha saṃvatsarasya prathama rātrir yā phalguni paurṇamasī I (6.2.2.18*),* While the *Vedāṅga-jyotiṣa* takes it as the *Dhaniṣṭhā nakṣatra.*

> *svar ākarmete somārkau yadā śakam savāsavau I*
> *syād tadādiyugam.*

'When the sun and the moon, while moving in the sky, come together to *Vasava* (*Dhaniṣṭhā*) star, then is the beginning of *yuga*'.

(*ṚV. Vedāṅga-jyotiṣa*, 5).

The Stars

As in other matters, in the study of the stars also, religion and astronomy have gone together hand in hand in Vedic India. The *Taittirīya Brāhmaṇa* has a passage inculcating the divinity of the stars and stating the need to perform rites under auspicious stars.

'*salilam vā idam antar āsīt* I *yad ataran* I *tat tārakāṇām tārakatvam* I *yo vā iha yajate* I *amum salokam nakṣate* I *tan nakṣatrāṇām nakṣatratvam* I *devagṛhā vai nakṣatrāṇi* I *ya evam veda* I *gṛhy eva bhavati* I *yāni vā imāni pṛthivyāś citrāṇi tāni nakṣatrāṇi* I *tasmād aślīlānāmaś citre* I *nāvasyen na yajeta* I *yathā pāpāhe kurute tādṛg eva tat* I' (*Tait. Br.* 1.5.2.10-11).

'There was water in the centre. They (the stars), crossed it, (and saved themselves). Hence the saving power of the stars. He who performs a sacrifice here, he goes to the world (of the stars). Hence the *nakṣatratā* of the stars. The stars are the abodes of the gods. He who knows this becomes the occupier of such a house. The stars are the images of worldly objects. Hence a rite should not be terminated or a sacrifice performed on a baneful star, for it would be like performing the action on a sinful day.'

This faith, naturally, made the Vedic people observe the stars and perform rites under those considered to be auspicious.

It is interesting to note a method that is ordained for the determination of the rising of a star. The following is a passage from the *Taittirīya Brāhmaṇa:*

Yat puṇyam nakṣatram, tadvat kurvīta upavyuṣam | *yadā vai sūrya udeti* | *atha nakṣatram naiti* | *yāvati tatra sūryo gacchet* | *yatra jaghanyam paśyet, tāvati kurvīta yatkārī syāt* | *puṇyāha eva kurute* | *eva ha vai yajñeṣum ca śatadyumnam ca mātsyo niravasāyayāñcakāra* ||

'The auspicious star, its position has to be determined at sunrise. But when the sun rises, the star would not be visible, (on account of the brightness of the sun). So, before the sun rises, watch for the adjacent star. By performing the rite with due time adjustment, one would have performed the rite at the correct time. Thus, it was that sage Matsya performed the sacrifices of *Yajñeṣu* and *Śatadyumna* to perfection' (*Tait. Br.* 1.5.2.1).

One finds in the *Vedas* beautiful pen-pictures of the helical rising of the stars. Here is a description of *Sirius* at vernal equinox.

suparṇā eta āsate madhya ārādhane divaḥ |
te sedhanti patho vṛkam tarantam yahvatīr apo ||

'High in the mind ascent of heaven, those birds of beauteous pinion (the stars), sit. Back from his path, they drive the wolf (Sirius), who would cross the restless floods.' (*ṚV.* 1.105.22).

The helical rising of the *nakṣatra Mūla* has been described in the *Atharvaveda (*2.8.1):

udagātām bhagavatī vicṛttau nāma tārake I
vikṣetriyasya muñjatām adhamam pāśam uttamam II

'Arisen are the two blessed stars called, *Vicṛtta-s.* Let them unfasten the *kṣetriya*, the lowliest, the highest fetter'. This helical rising which has been shown to have taken place in 3385 B. C., would give an indication of date of the *Ātharvaṇa* hymns.[7]

While there are references to *nakṣatra*s in general, the term was specially applied to the 27 well-known constellations that lie along the ecliptic, on the path of the sun and the moon. A Ṛgvedic verse specifies this:

atho nakṣatrāṇām eṣam upasthe soma āhitaḥ I
'The moon has been placed alongside the *nakṣatra*s!'

(*ṚV.* 10.85.2).

Another *Ṛgvedic* mantra speaks of thirty-four luminaries:

Catustriṃśatā purudhā vi caṣṭe sarūpeṇa jyotiṣā vivratena !

'with four and thirty lights, he (Indra) looks around him, lights of one colour, though their ways are diverse.' (*ṚV.* 10.55.3). The number, thirty-four, is explained to be made up of the sun, the moon, five planets and twenty-seven *nakṣatras.*

While the *Ṛgveda* mentions by name only a few *nakṣatras* viz., *Tiṣya (puṣya)* (5.54.13;10.64.8), *Citrā* (4.51.2) and *Revatī* (4.51.4), the *Taittirīya Saṃhitā* (4.4.10.1-3), *Maitrāyaṇīya Saṃhitā* (1.13.20), *Kāṭhaka Saṃhitā* (39.13) and *Taittirīya Brāhmaṇa* (1.5.1) enumerates them all, often with the figure they make in the skies. The *Atharvaveda* too enumerates several of the *nakṣatra*s.

Eclipses

Eclipses were observed during Vedic times and the real cause of the solar eclipse as the occultation of the sun by the moon, seems

to have been speculated upon. The *Ṛgveda* describes a total eclipses of the sun thus:

yat tvā sūrya svarbhānus tamasāviddhyad āsuraḥ I
akṣetravid yathā mugdho bhuvanāny adīdhayuḥ II
svarbhānor adha yad indra māyā avo divo vartamānā avāhan I
gūlham sūryaṃ tamasāpavratena turīyeṇa brahmaṇā vindad atriḥ II
*mā mām imam tava santam atra irasyā dugdho bhiyasā nigārīt*I
tvam mitro asi satyarādhāstau mehāvatam varunaś ca rājā II
grāvṇo brahmā yuyujānaḥ sarpayan kīriṇā devān namasopaśikṣan I
atriḥ sūryasya divi cakṣur ādhāt svarbhānor apa māyā aghukṣat II
yaṃ vai sūryam svarbhānus tamasā vidhyad āsuraḥ I
atrayas tam anvavindan na hy anye aśaknuvan II

(*ṚV.* 5.40.5-9).

O Sun, when the demon Svarbhānu overspread you with darkness, all the worlds stood as if not knowing where they were.

O Indra, you destroy the illusions of Svarbhānu which exist under the sky. Sage Atri got back the sun who was hidden by darkness, by means of his forth Brahma.

O sage Atri, may that malicious demon, desirous of food, not devour me with that dreadful darkness. You are a friend and truth is your wealth. May you and God Varuṇa protect me here.

The sage Atri set the press-stone, revered the gods with prayers and salutations and dispelled the illusions of Svarbhānu and set his eye on the sun's light (i.e., remained watching till the sun became free from darkness).

Atri and his descendants alone could restore the sun when the demon had overspread with darkness. None besides them had the power to do so.

It is interesting to note that, as against the later mythological conception of *Svarbhānu* (Rāhu) devouring the sun, here it is darkness that hides the sun. The mention in the *Aitareya Brāhmaṇa* (40.28), referred to earlier, that on new moon days, the moon enters the sun, is also pertinent here. All these would seem to indicate that the Vedic astronomer was on the right track in getting at the real cause of eclipses. An attempt has been made by P. C. Sengupta to study this eclipse and fix its date as 3928 B. C.[8]

In the *Tāṇḍya Brāhmaṇa* also, eclipses are referred to (vide 4.5.2; 4.6.13; 6.6.8; 14.11. 14-15; 23.16.2). At two of these places, sage Atri is credited with having removed the darkness (6.6.8; 14.11;14-15) and at the other places, the Devas.[9] In the *Gopatha Brāhmaṇa* (2.3.19), too, Svarbhānu is described to have hidden the sun with darkness and sage Atri to have retrieved him therefrom.[10]

Planets

The planets *(graha)* as distinct form the *nakṣatras* had been identified in the *Atharvaveda.* In 19.9.7 of that *Veda,* the poet invokes the blessings of the planets traversing the sky (*śam no divicarāḥ grahaḥ*) and two mantras later, in 19.9.9.,

invokes the blessings of the *naksatras.* (*nakṣatram ulkābhihatam śam astu naḥ*)

The number of the planets is given as five in the Ṛgvedic verse:

> *amī ye pañcokṣaṇo madhye tasthur maho divaḥ* I
> *devatrā nu pravācyam sadhrīcinā ni vāvṛtuḥ* ... (*ṚV.* 1.105.10).

'These mighty five (gods) are seen in the vast expanse of the sky. Even though they are seen coming together when I compose hymns in honour of the gods, they have all gone away today'.

Of the planets, which are best known and mentioned by name, one is Jupiter, who is spoken of thus:

> *bṛhaspatiḥ prathamam jāyamāno maho jyotiṣaḥ parame vyoman* I

'Jupiter was first born in the highest heaven of shining light'. (*Ṛ̣V.* 4.50.4)

Jupiter emerging from a conjunction with the constellation *Puṣya* is noticed in the *Taittirīya Brāhmaṇa. bṛhaspatiḥ prathamaṃ jāyamānaḥ tiṣyam nakṣatram abhisambabhūva* I (*Tait. Br.* 3.1.1.5)

The other planet which is mentioned by name is Venu. *Cf:*

ayam venaś codayat pṛśnigarbhā jyotir jarāyū rajaso vimāne I

'This Vena, child of Pṛśni, born in light, hath driven in a chariot of air'. (*Ṛ̣V.* 10. 123.1).

Meteors and Comets

There is an interesting reference in the *Atharvaveda* about meteors and comets which are supposed to portend evil. The poet invokes their blessings too, along that from others:

śaṃ no bhūmir vepyamānā śaṃ ulkānirhatam ca yat I
śaṃ no grahāś cāndramāsa śaṃ ādityāś ca rāhuṇā I
śaṃ no mṛtyur dhūmaketuḥ śaṃ rudrās tigmatejasaḥ II

'Weal for the quaking earth, and weal for the meteor-smitten. Weal for us be the planets belonging to the moon and weal the sun with *Rāhu.* Weal for us the deadly comet, weal the Rudras of keen brightness'. (*AV.* 19.9.8-10).

Vedic astronomers

The discipline of astronomy having gained the distinction of being called *Nakṣatra-vidyā,* one comes across in Vedic literature, the names of a few teachers and students of the subject.

Sage Atri and his descendants who specialized in eclipses have already been mentioned. A reference has been made also of Matsya who got performed a rite at the rise of a specific constellation. The *Taittirīya Brāhmaṇa* lists a line of adherents who attained bliss as a result of mastering the discipline. Thus, after setting out the minute divisions of time, which are said to be the counter-forms of the sun (*Savitā*), the *Brāhmaṇa* describes the benefits of its study:

Janako ha vai vaidehaḥ I ahorātrais samājagāma I tam hocuḥ I yo vā asmān veda vijahat pāpmānam eti I sarvam āyur eti I abhi svargam lokam jayati I nāsyāmuṣmin loke 'nnaṃ kṣīyate I ya evaṃ veda... ahīnā hāśvatthyaḥ I sāvitram vidāṃ cakāra I saha haṃso hiraṇmayo bhūtvā svargam lokam iyāya I ādityasya sāyujyam I ...devabhāgo ha śrautarṣaḥ sāvitram vidāṃcakāra I tam ha vāg dṛśyamānā 'bhyuvāca I sarvam bata gautamo veda I yas sāvitram vedeti I ...tasmād ye ke ca sāvitram viduḥ I sarve te jitalokāḥ...śūṣo ha vai vārṣṇeyaḥ ādityena samājagāma I taṃ hovāca I ehi sāvitram viddhi...

The Vaideha (King), Janaka went with days and nights, (the units of times defined earlier). (About the benefit of such study), they told him: He who understands us becomes sinless; he lives a full life; he attains to the heavens; for him food will not be scarce in this world...

Ahina, son of Aśvattha, learnt the science of the sun. He became a swan and ascended the heavens and was merged in the sun.

The *Śrauta* priest Devabhāga learnt the science of the sun. The invisible goddess of speech told him: Gautama who knew the science of the sun knows everything... Hence those who know the science of the sun, they overcome the world....

Śuṣa, the son of Vṛṣṇi, went with the sun. The sun told him: Come and learn the science of the sun... (*Tait. Br.* 3.10.9).

REFERENCES:

1. *Cf. Yajurveda, Vājasaneyī-Saṃhitā, 3.10; Taittirīya-Brāhmaṇa, 3.4.4.*
2. *Cf. Yajurveda, Vāj. Saṃ. 30.20; Tait. Br., 3.4.15.*
3. Mentioned along with the other disciplines of study in the *Chāndogya Upaniṣad* 7.1.2.4.
4. On this, see K. V. Sarma, *A History of the Kerala School of Hindu Astronomy,* Vishveshvaranand Institute, Hoshiarpur, 1972.
5. For some such anticipations, see *ibid.*, pp. 11.28.

6. For an analytical study of these and other references and their dating, see P. C. Sengupta, *Ancient Indian Chronology,* University of Calcutta, 1947, pp. 155-74, sn. on 'Solstices in Vedic literature and *Yajurveda* antiquity'.

7. See P. C. Sengupta, *Ancient Indian Chronology,* University of Calcutta, 1947, pp. 132-36.

8. See the sn. on 'The Solar eclipse' in the *Ṛgveda* and the date of Atri, in his book, *Ancient Indian Chronology,* op. cit., pp. 101-31.

9. These three references are with regard to the same eclipse, which Sengupta, shows to have taken place in 2450 B. C. Vide sn. on 'Solar eclipse in the *Tāṇḍya Brāhmaṇa*', op. cit., pp. 175-82.

10. On Atri's descendants being expert students of astronomy, see *AV,* 13.2.4; 13.12.36; *Śatapatha Brāhmaṇa,* 4.3.4.21.

VEDĀṄGAJYOTIṢA : A CRITICAL STUDY*

Vedāṅga-Jyotiṣa, the astronomical ancillary of the Vedas, ascribed to Lagadha, (C. 1180 B. C.), is a rather difficult text; difficult, not on account of the language or style, but for reasons other than these, which however, are not far to seek. The work is really a practical manual for vedic priests towards enabling them to calculate the times of the full and new moons, the days of the last appearance of the moon and its first appearance in the fortnight, the moon's asterisms and certain other matters, the knowledge of which is essential for the determination of the times of several vedic rituals and other religious observances. Unlike the later astronomical *Siddhāntas* and *Karaṇas* the *Vedāṅga-Jyotiṣa* does not give exact definitions of the technical terms used, nor does it spell out in any detail the procedures involved in the calculations. These, work takes for granted, to be known to the vedic priests who had derived them for traditional instructions. For this reason, the modern scholar, who does not have the tradition handed down to him, has necessarily to conjecture the meaning of the technical terms and to reconstruct the methodologies of calculations himself basing upon the dictums of later astronomical developments. This accounts for the substantial differences that are met within the exposition of the *Vedāṅga-Jyotiṣa* by Jacobi, B. G. Tilak, S. B. Dikshit, Sudhakara Dvivedi, Lala Chote Lal alias Barhaspatya, Shama Sastry, Satish Chandra Bhattacharya, H. M. Yajnik and T. S. Kuppanna Sastry, to mention some of the scholars who have handled the subject.

Still another difficulty which faces the modern scholar relates to the correctness of the text. This difficulty is really more serious, since a corrupt reading of a literary nature or a grammatical fault is easily identified and corrected or amended, than a corrupt terminology numerical error or a mathematical step, which would be possible only if the correct terminology and computational methods known to the vedic priests are also known. Since this is mostly not the case, even

**Treasures of Ancient Indian Astronomy*, Ed. by K.D. Abhynkar & B.G. Siddharth, Ajanta Pub. New Delhi, 1993.

oral tradition and ancient scribes have simply perpetuated corrupt readings down the ages, a fact which has been attested by the examination of various manuscripts of *Vedāṅga-Jyotiṣa.*

A number of manuscripts of this work are available, both in its Ṛgvedic version (*Ṛ-VJ*) in 35 verses, and in its Yajurvedic version (*Y-VJ*) in 45 verses. A commentary on the work by Somākara Śeṣa is also available besides about ten editions. But, for the reasons stated above and possibly for other reasons as well, none of the manuscripts carry a really pure text as seen from a close examination of 20 independent manuscripts of the work, on the basis of which a critical edition thereof has recently been issued: *Vedāṅga-Jyotiṣa*, with the translation and Notes by T. S. Kuppanna Sastry, critically edited by K. V. Sarma Indian National Science Academy, New Delhi, 1984.

Of the 20 manuscripts used for the above said edition, 14 pertain to the *Ṛg-Vedāṅga-Jyotiṣa* and 6 to the *Yajur- Vedāṅga-Jyotiṣa*. Though these manuscripts came from different regions, belonged to different periods, and were inscribed on different materials in different scripts, the manuscripts *en masse* exhibited a number of common obviously corrupt readings. Which necessarily implied that the corrupt readings had been handed down traditionally through the ages. These included wrong words, omission of letters, and incorrect numerals, which required editorial correction and emendation. In the critical edition of *Vedāṅga-Jyotiṣa* referred above, all these corrections and emendations have been scrupulously set off within brackets, the actual readings in the manuscripts being given as footnotes. The necessity of these corrections have also been mostly indicated in the translation and notes that follow the verses.

It would be worthwhile to collect these corrupt readings, classify them and categorise them in order to see how these readings occurred and why they have survived.

In all about 80 corrections or emendations had to be made in the critical edition. It is to be stressed here that a correction or

emendation has been made only when all the manuscripts gave a wrong reading. If, at least, one of the manuscripts contained the correct reading, that reading would have been taken as the text reading and so no correction or emendation was involved here. The two recensions of *Vedāṅga-Jyotiṣa* have 28 verses in common (with differences in two or three verses), the remaining verses, 7 in the case of the *Ṛg* recension and 17 in the *Yajus* recension, being independent. The corrections might be classified into four types.

A. When both *Ṛ - VJ* and *Y - VJ* have a common corrupt reading.

B. When either *Ṛ - VJ* or *Y - VJ* is corrupt and so one corrupts the other.

C. When *Ṛ - VJ* is corrupt in its independent verses.

D. When *Y - VJ* is corrupt in its independent verses.

The reasons for the occurrence of the corrupt readings might be categorized as follows:

1. Corrupt readings going back to the oral tradition when the system began to fall into disuse and archetypes of manuscripts began to copy the wrong oral tradition.
2. Corrupt readings in manuscripts being copied and recopied by scribes as such and checked by revisers who left them like that, since the meaning had become obscure.
3. Phonetic distortions causing scribal errors.
4. Substitution of easier and well-known words in place of the unintelligible ones.

Here in below have been set out, in the form of Tables, the several corrections and emendations made in the critical edition, arranged according to the above-said four types, with the possible reasons for the occurrence of corruptions noted against each correction or emendation, the corrupt readings in the manuscripts also being given side by side for comparison.

A. Common corrections in *Ṛ-VJ* and *Y-VJ* Manuscripts

No.	*Ṛ. VJ* Mss.	*Y-VJ* Mss.	Correction/ Emendation	Cause/ Purpose
1.	8c. caiva dvi	9c. caiva dvi	ca dvi	Caiva is nonmetric and eva is superfluous
2.	12a. triyaṃśī, triyaṃśo, tryahaṃśa, tryahaṃśo,	27a. tryahaṃśi, tyiyaṃśī, triyaṃśo	tryaṃśo	Phonetic distortion
3.	16b. Syād dvi	38b. syādvi, syād dvi, syād dviḥ	syād dve	Context requires *dve*
4.	16c. dvitriṃśat	38c.dyutriṃśaśas dvitriṃśat	dyutriṃśat	Do. Also phonetic distortion
5.	22c. tad eva ṣaṣṭyā	40c. tad eva ṣaṣṭyā	tad eka ṣaṣṭyā	Do. Also *eva* is superfluous
6.	24c. gatan vyastan, gate bhyastam, gatabhyastam	42c. gābhyastan gatan vyastan, gatanyastam	gatabhyastam	Do

B. *Ṛ-VJ* and *Y-VJ* Correct one another

7.	5d. śuklo dinam tyajaḥ	6d.śuklo'yanam hyudak	śuklo'yanam hyudak	Gives correct sense.
8.	9d.pañcanabha	10d. pañcama-bhastvṛtuḥ	pañcamabha	Do and phonetic distortion

No.	*Ṛ. VJ* Mss.	*Y-VJ* Mss.	Correction/ Emendation	Cause/ Purpose
9.	10c. guṇasyona	15c.guṇaśconaḥ	guṇaśconaḥ	Do
10.	11a. bhāṃśāṣṭakā	19a.bhāṃśā-ṣṭakasthāne	bhāṃśāṣṭaka-sthāne	Do
11.	11c. dvisapta	19c. trisapta		Do
12.	11d. pratirudvapeta	19d.timudvapet	trisapta	Do
13.	12b. daśasyāpyupanīta	27b.śaścāpanīya	timudvapet śaścāpanīya	Do
14	12c. cādhigate pare 'ṃśe	27c. cāpigate paro 'ṃśo	cāpigate paro 'ṃso	Do
15.	14b. somādhānaḥ, somānānaḥ	18b. sū mā dhā ṇah	sū mā dhā ṇaḥ	Do
16.	15c. caturdaśī	17c.caturdaśyām	caturdaśyām	Do
17.	16a. ca viśā	38a. saviṃśā	saviṃśā	Do
18.	18a. sasaptakuṃ	29a.sasaptakaṃ	sasaptakaṃ	Do
19.	18a. syonaḥ	39b. somaḥ	somaḥ	Do
20.	18b. sūryādyonim	39b. sūryo dyuni	sūryo dyuni	Do
21.	20a. bhāgeṣu, bhāge tu	22a. bhāgebhyaḥ	bhāgebhyaḥ	Gives correct sense
22.	24b. bhūyo 'pyenaṃ	42b. bhūyo 'pyahnaḥ	bhūyo' pyahnaḥ	Do
23.	24c. jñeyarasim	42c. jñeyarasiḥ	jñeyarāśiḥ	Do
24.	24d. rāśiṣu	42d. rāśinā	rāśinā	Do
25.	29a. ityetanmāsa	42. (unnumbered) ityevam māsa	ityevam māsa	Do
26.	29d. vyākhyātam	42.(ununmbered) vyākhyānam	vyākhyānam	Do

No.	*Ṛ. VJ* Mss.	*Y-VJ* Mss.	Correction/ Emendation	Cause/ Purpose
27.	30a. sūryastri sūryatri	43a. suryastu	sūryastu	Do
28.	30a. carito, caritaḥ, jarito	43a. caritam	caritam	Do
29.	30c. sūryastri	43c. sūryastṛ	sūryastṛ	Do
30.	30c. carito, caritaḥ, jarito	43c. caritam	caritam	Do

C. *Ṛ-VJ* Independent verses : Emendations

No.	*Ṛ. VJ* Mss.	Correction/ Emendation	Cause/ Purpose
31.	17b. māṣakam, mūṣakam	āḍhakam	Phonetic distortion, gives correct senses
32.	19a. guṇābhyāstān, bhagaṇāstān	gaṇābhyastān	Do
33.	19c. sūryān	staryān	Do
34.	30b. lokāt, lokāl, lokān, lokam	lokam	Do
35.	31d. tathordhvam	thathārdham	Do
36.	32a. pravṛttastu	pravṛttasya	Do
37.	33b. māsīṃ trayodaśīm	māsīm athāsite	Do
38.	33d. dvādaśyām ca, dvādaśyāyana	dvādaśīṃ ca	Do

WORD AND ALPHABETIC NUMERICAL SYSTEMS IN INDIA*

Need for numerical systems:

Word or object numerals (*bhūta-saṃkhyā*) and Alphabet or Letter numerals (*akṣara-saṃkhyā*) formed a natural development aimed at the concise expression of numbers with ease in the fast-growing scenario of scientific development in ancient India, in the fields of astronomy and mathematics in particular. Naturally enough, in the actual formulation and expression of these two numerals were involved certain characteristics of the language of Sanskrit which functioned as the primary vehicle of culture in India from the earliest times. Metric form and brevity of expression constituted two of these characteristics. In fact, the extraordinarily large quantum of literature produced in early India had been couched in the metric or aphoristic form which conduced to their study by rote and preservation in memory. Then again, abridgements and abbreviated terms were quite common in the range of Sanskrit literature on account of the natural propensity and adaptability of that language. An example or two might be cited in illustration. In the *Vedāṅga-jyotiṣa* the twenty-seven asterisms of Indian astronomy are denoted by abbreviation (*ṚV-Vj.* 14-15; *YV-Vj.* 17-18)[1]. Thus *jau* stands for the asterism *Āśvayujau* and *drā* for *Ārdrā*; and so on. In Sanskrit grammar the abbreviation ac (अच्) represents all the thirteen vowels and hal (हल्) represents all the consonants. Herein lies the genesis of the Word and Alphabetic numerals which are profusely employed in Indian astronomy and mathmatics and, to a lesser extent, in other disciplines as well.

The numerical systems:

Several numerical systems based on full-fledged words and on individual letters of the alphabet had been devised in India at different periods, in different places to cater to general and specific needs.

**The Concept of Śūnya* (Ed. by A.K. Bag and S.R. Sarma) IGNCA,INSA, New Delhi, 2003

Word-numerals were evolved earlier and are traceable to Vedic literature. They occur in several modes such as single words, groups with place value and in the reverse where numbers denote objects. Short numerals like *dvi* and *tri* are found to intermingle with word numerals. Alphabetic numerals, which came later, have been developed by assigning different values to vowels, consonants, conjunct consonants and their components and also the placement thereof, mostly with some sequence and logic behind them. In some of the systems, however, the assignment of values appears to be purely arbitrary and adhoc.

Word Numerals

Nature of Word Numerals:

The word-numeral, or to be more exact, 'object-numeral' (*Bhūta-saṅkhyā*) refers to a system of numerical notation where a word denoting an object, concept, idea or group implies, besides its normal meaning, a number also by dint of meaning, convention or usage and, for that reason, that word is used to denote the number in question. Thus the number 4 can be denoted by one or the other of the words like *veda, varṇa, āśrama* or *yuga,* which are all groups of four. The number 2 can be denoted by any word which exists only in pairs like the eyes, arms and the like. *Rudra* denotes 11 since the *rudra* deities are eleven in number. In the same way *rada* (teeth) would denote 32 and *nakṣatra* (astrerism) 27. The synonyms of a word numeral can also be used to indicate the number in question. The phenomenal number of synonyms, each of varying lengths and containing differing number of syllables with differing alterations of short and long syllables, made these word-numerals extremely amenable to be fitted in appropriately into verses in different metres.

In actual usage these word-numerals as also ordinary numerals, which are also often found interspersed, are treated just as any other word with the addition of all types of grammatical complements like gender, affixes, suffixes and the like, so that they merge into the verse and do not appear to be extraneous interpolations, The words in the

verse other than the word-numerals serve to explain the procedures and computations or other matters involved, as the case may be. Then again, a word-numeral standing by itself denotes only itself, without place value for instance, *atyaṣṭi*, being the name of the metre having 17 syllables in a quarter, would denote the number 17. Long numbers are formed by appropriate word-numerals being placed one after the other, with place value, and read from right to left according to the principle *aṅkānām vāmato gatiḥ*, that is, 'the way of placing the numerals is from right to left'. Thus the expression *kha-rāma-guṇa-candraiḥ guṇayet* would mean 'Multiply by 1330'. The words which are conventionally employed as word-numerals number more than 800 well beyond their enumeration here. They have been compiled and presented as an Appendix by K.S. Shukla to his edition of *Vaṭeśvarasiddhānta*, Part I (INSA, New Delhi, 1986). Extracted below as Appendix I.)

It is necessary to note that it is only in India and in the Sanskrit language among all the world languages that word-numerals have been profusely used to represent numerals, from as early as before the Christian era.

Word-Numerals in the Reverse:

It is interesting that sometimes certain objects which occur only in numbered groups are denoted by the total number of items in the respective groups. For instance *dvādaśa* (12) is used to denote the 'year' which has twelve months and *sapta* (7) to indicate objects which occur in groups of seven like the oceans and planets.[2]

Provenance and Popularity

The Vedic Texts

The use of word-numerals has been an all-India phenomenon from very early times, especially in North India. On account of Sanskrit having been the main language in which literature was produced in ancient India, writers in several disciplines have adopted the device of the word numeral notation to depict numbers in their works. However

it was authors of texts on astronomy and mathematics that benefited most since those two disciplines were centred on numbers.

From among the Vedic texts where word-numerals occur might be mentioned *Kātyāyana-Śrautasūtra* and *Lāṭyāyana-Śrautasūtra* where the words *Gāyatrī* and *Jagatī*, being metres having specific numbers of syllables, are used to denote 24 and 48 respectively.[3]

The four fractions 1/16, 1/12, 1/8 and 1/4 are denoted in Vedic literature respectively by the words *kalā* (*ṚV.* 8.47.17), *Kuṣṭha* (*YV. Maitrāyaṇīyasaṃhitā,* 8.7.7) , *śapha* (*ṚV.* 8.47.17) and *pāda* (*ṚV.* 10.90.3-4). The word-numeral *rūpa* (1) occurs in the *Ṛ -Vedāṅgajyotiṣa* 31.

In the *Agnipurāṇa* word-numerals occur prominently in several of the chapters like *Kālajñāna* (ch.122).[4]

General Disciplines

Several of the texts in *Tantraśāstra*, for instance, *Śāradātilaka*.[5] *Tantrasamuccaya* of Nārāyaṇa[6] and *Mayamata*[7] make use of the word numeral notation., In music the *Caturdaṇḍiprakāśikā* of Veṅkaṭamakhin designates the twelve divisions of his musical scheme as *indu* (1), *netra* (2), *agni* (3), *veda* (4), *bāṇa* (5), *ṛtu* (6), *ṛṣi* (7), *vasu* (8), *brahmā* (9), *dik* (10), *rudra* (11) and *āditya* (12). Coming to architecture, the *Śilparatna* uses the word-numerals in measurements relating to the construction of the eight-storey edifice.[8]

Inscriptions

Inscriptions too have their dates inscribed in word-numerals. The earliest instances are to be found in two Sanskrit inscriptions dated *śaka* 526 (A.D. 604) and 547 (A.D. 625) discovered in Java at which period it was an Indian colony.[9] Inscriptions and copperplates too have their dates inscribed in word-numerals.[10]

Colophons of manuscripts

Colophons of texts and post-colophonic statements by scribes of manuscripts too give their dates, at times, in word-numerals.[11]

Astronomy and Mathematics

The greatest impact of the system was on the twin disciplines of mathematics and astronomy whose mainhold was numbers. These two sciences underwent an efflorescence in India from about the beginning of the Christian era from when on numerous works came to be produced. Practically all the major astronomers and mathematicians of the period took full advantage of the system for depicting, in simple graceful verses, the fundamental parameters and computations involved in their works.[12] These included, among others, the promulagators of the five *Siddāntas Paitāmaha, Vāsiṣṭha, Pauliśa, Romaka* and *Saura* epitomized in the *Pañcasiddāntikā* of Varāhamihira, Bhāskara I, Brahmagupta, Śrīdhara, Bhaṭṭotpala, Śrīpati, Vaṭeśvara, Bhāskara II and a host of others, mainly from North India, who came later. Some of the prominent scholars of South India like Parameśvara of Vaṭaśreṇi and Nīlakaṇṭha Somayāji also used the system extensively.[13]

Alphabetic Numerical System

Kaṭapayādi-I System -Nature of the System

Far more facile and much more versatile than the word-numeral system is the *Kaṭapayādi-I* alphabet system developed in Kerala. Here individual letters of the alphabet are adapted in a logical manner to represent the digits 1 to 9 and zero, and arranged in the traditional way of right to left to form numbers. The virtuosity of the system stems from several factors. First, each of the digits and zero could be represented by any of several specified letters. Conjunct letters and single letters could have any vowel attached to them and can take any case-ending whatsoever and function accordingly without any alteration to their values. These two aspects enabled one to weave words and expressions which could retain their normal meanings, form meaningful phrases and merge into metrical verses and, at the same time, represent the intended numbers as well. To cite an example, the word *āyurārogyasaukhyam*, with which the well-known work *Nārāyaṇīyam* of the devotional poet of Kerala, Nārāyaṇa Bhaṭṭa closes, sets out the

date of the completion of the work in *Kali* days as 17,12,211 by the *Kaṭapayādi* notation. Besides this the expression gives, along with the other words of the verse, its normal meaning, being the prayer of the author for longevity (*āyus*), health (*ārogyam*) and happiness (*saukhyam*). The significant advantage of the system lies in the fact that the short and crisp numerals formed carry contextual meanings also through full-fledged and grammatically correct expressions which make them easy to memorise and render them not liable to corruption in speech or in writing. Also, if-ever a doubt arose the same could be checked through meaning and grammar.[14]

The System Explained

Conversion of even long numbers into *Kaṭapayādi* and the formulation of tables of different types can be effected with ease. The art is practiced even today by the astronomers and almanac makers of Kerala in their works.[15] The several almanacs issued every year in Malayalam by Kerala astronomers and the horoscopes for new-born babies prepared by the astrologers of the land have dates set out in the *Kaṭapayādi* system. The reason for this lies in the simplicity and straightforwardness of the system. Here all vowels are taken as zero and those affixed to consonants are ignored. The consonants alone are taken to represent the digits and are taken in the order in which they occur in the Sanskrit alphabet. In the case of conjunct consonants, the last component alone is taken as a digit. Thus the ten letters from *ka* to *ña* represent 1 to 9 and zero. Then the ten letters *ṭa* to *na* are again taken to represent 1 to 9 and zero, and the next five letters *pa* to *ma* are taken as 1 to 5 and the last nine letters *ya* to *ḷa* are taken as 1 to 9. It is to be noted that *ḷa* is a distinct letter of the alphabet in the Malayalam and other South Indian languages as in the *Veda*. The rule for *Kaṭapayādi*-I is given by the verse:

na-ñāvacaś ca śūnyāni, saṅkhyāḥ kaṭapayādayaḥ /
miśre tūpāntya-hal saṅkhyā, na ca cintyo halasvaraḥ //
(*Sadratnamālā* of Śaṅkaravarman, 3.3)

'*na, ña* and the vowels are zero. The letters (of the consonant groups) commencing with *ka, ṭa, pa* and *ya* are digits. In conjunct letters the last consonant is to be taken as the digit. A consonant not attached to a vowel is to be ignored.'

Date of the System

Āryabhaṭa (born A.D. 476), who designed his own system of alphabet numerals, was conversant with the *Kaṭapayādi* system as shown by his commentator Sūryadeva Yajvan while explaining the word *Kāt* in *Āryabhaṭīya* 1.2 (see edn. INSA, New Delhi, 1976, p.10). Vararuci, the Kerala astronomer who prepared the table of the moon's daily angular motion (*candravākyas*) using the *Kaṭapayādi* system lived in the fourth century A.D. Another early work which makes use of the *Kaṭapayādi* notation is the *Upadeśasūtra* or *Jaiminisūtra* on astrology by Jaimini.[16] However it is difficult to accept the identification of this author with Jaimini, author of the *Mīmāmsasūtras* and the statement that "the system probably existed even as early as the fifth century B.C.," and even earlier since "The *Mahābhārata* is called *Jaya* 'because' *jaya* in *Kaṭapayādi* system means eighteen".[17]

Provenance and Popularity

The popularity of the *Kaṭapayādi* system in Kerala has been phenomenal. This is not surprising because one of the texts prescribed for children when they commenced their studies according to the traditional method, a system which extended from very early times and continued till recent times, was the *Candravākyas* (Table of Moon-sentences) composed in *Kaṭapayādi* by Vararuci. The acquaintance with the *Kaṭapayādi* notation imbibed when young, enabled writers of every discipline to use this facile system of expressing numbers whenever there was a need. Thus whatever be the subject of a text, *Veda*, Philosophy, *Dharmaśāstra, Tantra, Śilpa, Vaidya, Vyākaraṇa, Saṅgīta* or *Kāvya*, the authors often indicated the *Kali* dates of completing their works in *Kaṭapayādi* and much more so the scribes of the manuscripts in their post-colophonic statements. Vedic students used to identify, remember and recollect the chapter and verse of the

texts through *Kaṭapayādi* abbreviations. Nārāyaṇa Bhaṭṭa of Melputtūr has documented the *aṣṭaka* divisions and *varga* sections of the *Ṛgveda* through the *Kaṭapayādi* notation in a short work called *Sūktaślokāḥ*.[18] It needs to be added that in its non-technical normal sense the entire work forms a eulogy on the Mother Goddess. Wordy acrobatics using the system were also not absent among Kerala poets.[19] The system has been adopted by the discipline of music as well. The *Caturdaṇḍiprakāśikā* of the 17th century musicologist Veṅkaṭamakhin who has classified the *rāga*s of South Indian Carnatic music gives the names of the 72 *rāga*s in such a manner that the first two letters of each name gives the number of the *rāga* in the *Kaṭapayādi* system. The rest of the letters in the names give some characteristic of the relevant *rāga*. For example, no.9 is termed '*dhuni*'-*bhinnaṣaḍja*; no.28 is '*hari*'-*kedāragaula*.[20]

However, it was in the disciplines of astronomy and mathematics, which revolved around numbers, that the fullest use of the *Kaṭapayādi* numerals was made, especially in the formation of the constants, parameters, multipliers, divisors and the large number of sine tables involved in different computations. It is instructive to note here that in Kerala periodical revision of the parameters and tables had been directed by competent astronomical authorities like Parameśvara of Vaṭaśreṇi (A.D. 1360-1455), [21] Nīlakaṇṭha Somayāji (1444-1545)[22] and Jyeṣṭhadeva (1500-1610).[23]

It has to be noted that under the influence of such guiding instructions a large number of astronomical manuals (*Karaṇa*-texts) and tracts of different epochal dates, with differing parameters and sine tables (*jyā*s) have come to be composed in the land. Apart from these a large number of texts catalogued merely as '*jyā*s' are preserved on the shelves of manuscript repositories in Kerala.[24] This manuscript wealth, wherein all numbers are represented in the *Kaṭapayādi* system, would be a pointer to the wide prevalence of the system in Kerala.

From Kerala the *Kaṭapayādi* system has flowed over to the neighbouring region of Tamilnadu and to a lesser extent to the Telugu and Kannada-speaking regions. Almanacs in Tamilnadu are generally called *Vākyapañcāṅga*, 'Almanac based on mnemonic phrases'.

In their computation, while true moon is calculated using the 248 Moon-senctences of Vararuci, the true planets are computed using 2075 planet-phrases which go by the name *Samudravākya*s or *Maṇḍala-vākya*s, all set out in *Kaṭapayādi*.[25] Still another astronomical *Karaṇa* text produced in Tamilnadu is the *Tantraratna* of Gopendra Tippabhūpāla (fl.A.D.1475) who has composed his own tables of 248 *Candravākya*s correct to the seconds in *Kaṭapayādi* notation.[26]

The Jain School of mathematics of the Karnataka region involves substantial mathematical material even in their religious and philosophical works like the *Trilokasāra, Gommaṭasāra* and *Labdhisāra* of Nemicandra Siddhāntācārya (9-10 cent.) wherein full use of the *Kaṭapayādi*-I system is made; vide sn. on '*Symbolism and List of working symbols*', on pp.59-61 of vol. I of *Labdhisāra*, ed. By L.C. Jain (Katni,1994).

Alphabet-Numerals of Āryabhaṭa-I

Nature of the System

Āryabhaṭa (b. A.D. 476), astronomer and mathematician who flourished at Kusumapura (Patna), was aware of the *Kaṭapayādi*-I system[27] wherein full-fledged letters, single and conjunct, with vowels attached, represented a single digit. Obviously, with a view to prune that system further, Āryabhaṭa devised another system in which a consonant-pure, i.e. a consonant without a vowel attached, represented not only signle digits but also double-digited numbers. A conjunct consonant was to be the sum of all the numbers of its components. Each vowel indicated an odd and an even place, in the ascending order, as to where a digit was to be placed to form a number.

The system

Āryabhaṭa enunciates the system in the verse:

वर्गाक्षराणि वर्गेऽवर्गाक्षराणि कात्, ङ्मौ यः ।
खद्विनवके स्वरा, वर्गेऽवर्गे नवान्त्यवर्गे वा ।। (*Āryabhaṭīya* 1.2)

'While deciphering numbers from the alphabet-numerals of this system the varga letters (i.e. the 25 letters *k* to *m* being five each of the five *vargas*, *k, c, ṭ, t* and *p* of the Sanskrit alphabet, with the assigned values 1 to 25) should be written in the *varga* places (or odd places, i.e. 1st, 100th, 1000th etc. which are *vargas* or squares) and the (eight) *avarga* letters (*y* to *h*) with the assigned values 30 to 100 should be written in the *avarga* (or even) places; *ṅ* and *m* (i.e, 5 and 25) together make *y* (or 30). Assign eighteen zeros (to represent 18 notational places, two each to the nine) vowels (a to au) which will indicate the *varga* or *avarga* places (where the letters to which they are attached should be placed). For numbers bigger than 18 notational places repeat with another set of vowels or with some other difference.'[28]

Continuing, Āryabhaṭa gives in his numeral system the eastward revolutions of the planets:

युगरविभगणाः ख्युघृ शशि
चयगियिङुशुछ्लृ कु ङिशिबुण्ऌष्खृ प्राक्
शनि ङुङ्विघ्व, गुरु ख्रि
च्युभ, कुज भद्लिझ्नुखृ, भृगुबुधसौराः (*Āryabhaṭīya* 1.3)

Thus the eastward revolutions per aeon of the Sun are *khyughṛ* or 43,20,000; of the Moon *cayagiyiṅuśuchlṛ*, 5,77,53,336; of the Earth *ṅiśibuṇlṛṣkhṛ* or 1,58,22,37,500, of Saturn *ḍhuṅvighva* or 1,46,564, of Jupiter *Khrichyubha* or 3,64,224; of Mars *bhadlijhnukhṛ* or 22,96,824; of Mercury and Venus, the same as that of the Sun.

Though the chronograms formed by this system are formed logically and are extraordinarily brief, this advantage is offset completely by their not being amenable to be freely pronounced, copied with confidence, memorized with ease, not suffixed with a case-ending nor fitted into a verse or formula. Moreover they lack elegance and

have no literary sense whatsoever and so it is practically impossible to be checked or corrected in case of doubt. It would seem that the system had no takers. Neither has any later astronomer employed this numeration nor is it found in any inscription.

Kaṭapayādi-II System of Āryabhaṭa II

The System Explained

Āryabhaṭa II who wrote his *Mahāsiddānta*[29] in about A.D. 950 modified the *Kaṭapayādi*-I system with some innovations and devised the *Kaṭapayādi*-II system for use in his work. The rule is:

रूपात् कटपयपूर्वा वर्णा वर्णक्रमेण भवन्त्यङ्काः/
ञनौ शून्यं, प्रथमार्थे आ छेदे, ऐ तृतीयार्थे// (*Mahāsiddhānta* 1.2)

(The four groups of) consonants beginning with *k, ṭ, p. y*, each from 'one' (*rūpa*), function as digits; *ñ* and *n* represent zero. (Chronograms expressed) in the nominative case (plural) and in the instrumental (plural) drop their (ending *visargas*) and read with an ending *ā* and *ai*, respectively.'

An examination of the presentation of numbers in the *Mahāsiddhānta* provides some more information about the system. Thus, while accepting the values of the consonants, taking *ñ* and *n* as zero and the vowels attached to consonants as of no significance as in *Kaṭapayādi*-I, the new system gives values to all the components in a conjunct consonant. Thus *kya* means 11, not 1 as in *Kaṭapayādi*-I.

The deletion of the *visarga* is obviously intended to obviate the possibility of the *visarga* turning into the letters *r ś, ṣ* and *s* when euphonic combination (*sandhi*) takes place between the *visarga* and an amenable consonant following it (in an adjacent chronogram), thereby changing the number intended by the chronogram. For example, the chronogram *dāsāḥ cāṭu*, will remain as such if the words are given as *dāsā cāṭu* but will become *dāsāścāṭu* if *sandhi* is allowed. Then the digit for *ś* will get included in the chronogram and render the number different. It might be noted that in *Kaṭapayādi*-I such a contingency does not arise since chronograms are all composed by means of single

meaningful words. It is also to be noted that the above modification is prescribed only for nominative and instrumental plurals for the reason that chronograms are given only for setting out numbers in the nominative and to instruct their multiplication and division in the instrumental.

The most important modification, however, in this system lies in that the chronograms are given with the digits set out from left to right as sometimes practiced in early days and always so in modern times. Thus *manana* is 500 and not 005 which it would be according to *Kaṭapayādi*-I.

Limitations of the System

Obviously enough, Āryabhaṭa II enunciated his system of Kaṭapayādi with a view to simplifying it and incorportated an idea or two from Āryabhaṭa I's system. However, neither of these devices has been of much help on account of the inanity of the chronograms that have been concocted by the author.[30]

If the chronograms set in the numerals of Āryabhaṭa-I are not pronounceable and teeth-breaking on account of heavily packed conjunct consonants, those of Āryabhaṭa II are replete with liquid sounds and consecutive repetition of the same letters. See, for example, the revolution of the sun given by the chronogram *ghaḍaphenenanunīnāḥ* (1.7) and the number of civil days by the chronogram; *yaṇisasudhīkosīmeḍhīkhunīnonāḥ* (1.13). Here, there is always the possibility of tripping a letter or two not only in pronunciation but also in writing. In both systems, it is easy to err and difficult to check, with the result that both these letter-numerals had practically no takers.

In Pāli texts the *Kaṭapayādi*-I numeration is employed with a slight difference. The Pāli alphabet does not have the two letters *ś* and *ṣ* but has an additional letter *ḷ*. Hence the *Kaṭapayādi* numerals used in Pāli are identical with *Kaṭapayādi*-I except that after *v*=4, it is *s*=5, *h*=6 and *ḷ*'=7.

***Kaṭapayādi* in the 64 Arts**

From among the well-known sixty four Arts, the 46th *Mlecchita-vikalpa* ('Manipulation with incoherent speech') includes several manipulations. Of these *Gūḍhalekhya* ('Cipher wirting') uses *Kaṭapayādi* in a selective manner with facilities for coding and decoding, employing the formula:

Vedāṅgasārakṣapaṇāḥ sthāṇur lokahito varaḥ I

Coding is done using the first part of the formula by rewriting the letters of the passage which requires to be coded in the order 4 (*ve*), 8 (*dā*), 3 (*ṅga*), 7 (*sā*), 2 (*ra*), 6 (*kṣa*), 1 (*pa*) and 5 (*ṇāḥ*). Thus a secret message which reads: *rakṣakaḥ sukham svapiti* ('The guard is sleeping soundly') will be coded as: *sutikaḥ pikṣasva rakham*;, which is a nonsensical jumble of letters. When this is decoded by rearranging the letters in accordance with the second part of the formula, 7 (*sthā*), 5 (*ṇur*), 3 (*lo*), 1 (*ka*), 8 (*hi*), 6 (*to*), 4 (*va*), 2 (*raḥ*), the original passage is obtained.

Since the formula can accommodate passages only up to eight-letter codes, for a passage of more letters, the coding and decoding shall have to be repeated for every eight letters.[31]

Folio Numbering in Manuscripts

Nature of the System

Folios of manuscripts written on paper, *bhūrja-patra* and similar material are generally numbered by means of the normal decimal digits. The marking is made on the reverse side of the folios on the upper right hand corners, generally in line with the first row of the written matter. In the case of palm leaf manuscripts of South India, however, the folio numbers are inscribed with letter-symbols in the script in which the manuscript is written, on the middle of the left hand margin on the front side of the folios. This system of folio-numbering is known as *akṣara-pallī* (letter system) as contrasted with *aṅka-pallī* (digit system) wherein markings are done with digits.

Table of Letters used

On the basis of a detailed examination of a large number of manuscripts inscribed in different scripts and belonging to different periods, deposited in several institutions, Pt. Gaurishankar H. Ojha has prepared a fairly exhaustive table of letter-forms used for indicating folio-numbers in manuscripts.[32] Ojha's table adapted below gives the list of his findings with some later additions included:

1. e, sva, oṃ, śrī
2. dvi, sti, na, nna
3. tri, śrī, maḥ
4. ṅka, rṅka, ṅkā, eka, erka, rṣka, ṣkra, rph
5. tṛ, rtṛ, rtṛā, hṛ, nṛ, jhra
6. phra, rphra, ṛphra, ghra, bhra, rpu, vyā, phla, hā
7. gra, grā, rgbhrā, rggā, bhra, rgrā
8. hra, rhra, rhrā, dra, pra
9. oṃ, rūṃ, ru, uṃ, ūṃ, a, rnum, dre
10. lṛ, ḷa, ṇṭa, ḍā, a, rptā
20. tha, thā, rtha, rdhā, gha, rgha, pva, va
30. la, lā, rla, rlā
40. pta, rpta, ptā,. pna
50. ba, e, i, ṇū
60. cu, vu, ghu, thu, rthu, thū, rthū, rgha, rghu, ghu, tru
70. cu, cū, thū, rthu, rghū, rmta, tru
80. pu, cha
90. ṇa
100. su sū, rsṛ, ā, lū, rghū, ña
200. su, sū, rsu, ā, lū, rgh
300. stā, sūa, ñūa, sā, su, suṃ, sū
400. sūo, sto, stā.

It is to be noted that some of these letter-forms accord with normal letters in certain scripts but many of them are odd forms which

are not used in any language. Possibly they have been concocted with variations in order to distinguish them from the letters used in the languages. Some of them repeat in different languages with different values. However the question remains as to how these letter-forms which have no apparent sequence or meaning have been selected to represent the sequential numerals. It is clear, however, that *e, dvi* and *tri* which stand for 1,2 and 3 are the letters commencing the respective numbers, and *sva* = 1, *sti* =2 and *śrī* = 3, are the letters of the auspicious expression *svasti śrīḥ*. *śrī* = 1 is also such a word. In all cases, the second, and further letters representing the ten's and hundred's places are inscribed alongside the letter of the unit's place if there be space enough in the margin and otherwise one below the other.

Na-nna-nya-ṣkra scheme of Mss. in *Malayalam* Script

An alphabetical numeration scheme systematically followed in numbering folios of the plam leaf manuscripts in Kerala from early days to recent times is the *na-nna-nya-ṣkra* scheme where *na=1, nna=2, nya = 3, ṣkra = 4, jhra =5, hā = 6, gra = 7, pra = 8, dre = 9, ma = 10, tha = 20, la = 30, pta = 40, ba = 50, tra = 60, tru = 70, ca = 80, ṇa = 90, ña = 100.* Often the first folio is numbered with the letter *śrī* and the regular numbering commences from the second folio with *na*.

Folio-numbering in Mss. in Tamil Script

The Tamil language has not developed numerical symbols but uses some letters of its alphabet instead. The same alphabetic numerals are used in manuscripts also. Herein, 1 = *ka*, 2 = *u* , 3 = *na* with a dash at the foot, 4 = *ca* with an upward dash, 5 = *ru*, 6 = *cā* slightly modified, 7 = *e*, 8 = *a*, 9 = *ka* modified, 10 = *ya* rounded, 20 = *u* prefixed to the symbol for 10, 100 = ḷa without the initial loop, and 1000 = ta. Here again, it is hard to know the reason behind this apparently adhoc selection of the letters to represent the different numerals.

Folio numbers in Mss. in *Grantha* Script

The *Grantha* script which is used to inscribe Sanskrit texts in the Tamil region, too, has not developed numerical symbols and uses

some of the letters of its alphabet to represent the numerals. The same symbols are used in numbering manuscripts also. It follows Tamil numbering with slight variations. Thus, 1 = *ka*, 2= *u*, 3 = *na* modified, 4 = *ca* modified, 5 = *ru*, 6 = *cā* modified, 7 = *e*, 8 = *a*, 9 = *ka* modified, 10 = *dha*. It might be noted that the other Dravidian scripts have developed their own numeral symbols which are used also in numbering folios in manuscripts.

Sequential Development of the Alphabet for Numeration

Nature of the scheme

The order of the letters of the alphabet in a language, which must be well known to the users of that language, offered another logical method for alphabetic numeration. The devices of both Āryabhaṭas and the *Kaṭapayādi* systems utilized this method in part, to the extent they required it. The principle involved is to make a letter represent the serial number of the place occupied by it in the respective alphabets. Several systems with minor variations, have come up following this principle.

Pāṇini's use of Alphabet-Numerals

From among the nearly 4,000 grammatical rules (*sūtras*) framed by Pāṇini (c. 600 B.C.) for the Sanskrit language there are a number of 'head-rules' (*adhikāra-sūtra*s) which govern and overflow to several secondary rules to follow. While explaining *sūtra* 1.3.11, *svaritenādhikāraḥ*, Patañjali in his commentary *Mahābhāṣya* states that Pāṇini used to indicate by a sign the number of secondary rules which would be governed by it. Patañjali's commentator, Kaiyaṭa, explains how this indication is made when he comments on *sūtra* 5.1.30, *dvitripūrvānniṣkāt*. He says that through the indicatory syllable *i* here, which means two, Pāṇini instructs that the next two *sūtra*s would be governed by this *sūtra*. And, it follows that according to Pāṇini a =-1, i = 2, u =3, and so on, up to *ha*, the order of the letters being that given by him in his *Pratyāhāra-sūtras*, called also *Śivasūtras*.[33]

ka-kha-ga- Method

In Kerala some manuscripts number the folios with the consonants of the alphabet and not by the *na-nna-nya-ṣkra* method. Some manuscripts in the Telugu region also do so. In this scheme numbers 1 to 34 are marked by ka to ḷa, 35 to 68 by *kā* to *ḷā* (*ā* being added to the different consonants in place of (a), number 69 to 102 by *ki* to *ḷi* and so on.[34]

Several variations to the above are met with elsewhere. In Burma (now Myanmar) Buddhist manuscripts number the folios as *ka, kā, ki, kī* to *kaḥ* being numbers 1 to 12, *kha, khā* to *khaḥ* (13-24), *ga, gā* to *gaḥ* (25-36) and so on. It is to be noted that in this system, only twelves are used leaving the short and long of *ṛ* and of *ḷ* which are dropped. In the manuscripts of Srilanka (Ceylon), however, the folio numbers 1-16 would be represented by *ka* to *kaḥ*, 17-32 by *kha* to *khaḥ* etc. In the case of very long manuscripts when all the consonants have been exhausted, the numbering would restart with 2*ka*, 2*kā* etc.[35]

The methods of numbering folios of manuscripts described above pertain only to South India and the lands where South Indian culture had spread. It is also to be noted that these numerical symbols stand by themselves and are not incorporated into literature like the *Bhūtasaṅkhyā* and *Kaṭapayādi* systems.

In fine it has to be stressed that the ingenious device of word and letter numerals has facilitated the graceful and memorisable presentation of numbers in Sanskrit in the fields of mathematics and astronomy as much as the actual digits in calculation and computations.

REFERENCES:

1. *jau, drā ghaḥ khe śve 'hi ro ṣā cin mū ṣa ṇyaḥ sū mā dhā ṇaḥ /*
   re mū ghāḥ svā po jaḥ kṛ ṣyo ha jye ṣṭhā ity ṛkṣā liṅgaiḥ //
2. *Ṛgveda* (*ṚV*) 7.103.9: *devahitam jugupuḥ 'dvādaśasya'*: (They keep the god-appointed order of the twelve-monthed sun).

Atharvaveda (*AV*) 1.1.1: '*ye tri-saptāḥ paryanti viśvam*' (The three 'seven-groups' which go round the earth).

3. *Cf. dakṣiṇa gāyatrī-sampannā brāhamaṇasya* (*Kāt. Śs.* 22.11.21): Com. *Gāyatry-akṣara-samāna-saṅkhyāḥ caturviṃśatir gāvo dakṣiṇā. Jagatyā rājñaḥ* (*Kāt. Śs.*22.11.22). Com. *Jagaty-akaṣara-samāna-saṅkhyā aṣṭacatvāriṃśat gāvo bhavati.* See *Lāṭ. Śs.* 9.4.31 for a similar passage and similar comments.

4. See *Agnipurāṇa*, ch.122 (*Kālajñāna*):

   kālaḥ samāgaṇo, vakṣye gaṇitam kālalabdhaye /
   kālaḥ samāgaṇo 'rka-ghno māsaiś caitrādibhir yutaḥ //1//
   dvighno dvighno sa-vedaḥ syāt pañcāṅgāṣṭayuto guṇaḥ /
   triṣṭho madhyo vasaguṇaḥ punar vedaguṇaiś ca yaḥ //2//
   aṣṭarandhrāgnihīnaḥ syāt adhaḥ saika-rasāṣṭakaiḥ /
   madhyo hīnaḥ ṣaṣṭihṛto labdhyauktas tathopari //3//

   Here the words *arka* (12), *veda* (4), *vasu* (8), *randhra* (9), *rasa* (6) and *agni* (3) are all numerals.

5. *Cf. rudra* (12) *saṅkhyākṣaro manuḥ* (7.96)
6. *Cf. tattvā-ṣṭi-tattva* (25, 16, 25). (8.15)
7. *Cf. nanda* (9) *paṅktibhir* (10) *athendriyā* (5) *ṃśakaiḥ* (22.57)
8. See *Śilparatna* of Śrīkumāra:

   tadadho munibhiḥ sārdham guṇāmśaiḥ stambhakuṭṭimam /
   dharma-rudrā-rka-bhāgais tu satrayodaśamārgikaiḥ //
   aṣṭabhaumam vadanty asminn evam prājñā munīśvarāḥ //

   Here the numerals used are *muni* (7), *guṇa* (3), *dharma* (6), *rudra* (11) and *arka* (12).

9. See *Indian Antiquary*, 21 (1902) 48.
10. E.g. Inscription dates *Saṃ* 898 of Caṇḍamahāsena of the Chāhamāna dyanasty from Dholpur which reads: *vasunava aṣṭau varṣagatasya kālasya vikramākhyasya*; and copperplate of a gift-deed dated *Śaka* 867 of the Eastern Cālukya King Amma I: *giri-rasa-vasu-sakhyābde śakasamaye.*

11. For instance Haribhāskara closes his work *Padyāmṛtataraṅgiṇī* with the verse:

    āṣāḍhamāse suvalakṣapakṣe,
    'kha-vahni-sapt-endu-'mite śubhebde /

gurau navamyām agamat samāptim
sat-padyapīyūṣataraṅgiṇīyam //
(Mss. No. 15 and 510 in the Khasmohar Collection, City Palace, Jaipur).

The date of the completion of the work *Padyāmṛtataraṅgiṇī* of Haribhāskara as stated by the author is Thursday, in the bright fortnight of the month of *Āṣāḍha* in the year 1730.

For the mention, by a scribe, of the date of his completing the copying of a manuscripts, see:

'vahni-vedā-bdhi-candre 'ca śālivāhaśakābdike /
navamādhyāyaṭīkeyam likhitā tañjapattane //
(*Bhāgavata-vyākhyā*, Ms. Tanjore Sarasvati Mahal Library, Cat. No. 9959.)

Here, the year of copying the manuscript given in word-numerals is Śālivāhana-*Śaka* 1443.

12. See for instance, the directions for the computation of *avama* or omitted lunar days, in the *Mahābhāskarīya* of Bhāskara I:

saṃhatya randhra-yamalaiḥ (29) rasa-rāma (36) bhāgo
bhūyogni-veda (43) guṇiteṣu harec ca bhāgam /
kha-vyoma-kha-dvi-munibhiḥ (72,000) pralayas tithīnām
saṃyojya bhūta-yama-rudra (1125)-hṛte dināni //
(*Mahābhāskarīya* 1.23)

13. A typical instance of the documentation of very large numbers through graceful and sparkling verses might be cited here to illustrate the ease with which authors of astronomical texts handled the word-numerals.

47, 23, 32, 26, 54, 67, 510
vyom-aika-bāṇā-dri-rasā-bdhi-bhūta-
ṣaḍ-dvy-aśvi-rāmā-gni-yamā-dri-vedāḥ /
bhānor, vidhoḥ khā-bhra-khā-bhrā-bhra-netra-

3,53,30,86,62,00000
ṣaṭ-ṣaḍ-vasu-triṃśad-agnī-ṣu-rāmāḥ //

5,60,22,54,07,11,75,000
khā,bhrā-bhra-bāṇā-dri-śivā-dri-khā-bdhi-
tattvā-kṣi-śūnyā-ṅga-śarā-guroś ca/

kakṣayā imās tattva-nagāhiṣaṭka-

16,35,68,725

bhūta-gni-ṣaḍ-bhūmi-bhir āhatāḥ syuḥ //

(Parameśvara's sub-com. *Siddhāntadīpikā* on the *Bhāṣya* of Govindasvāmin on the *Mahābhāskarīya*, 1.52. edn., p.85).

The four numbers documented above have, respectively, fifteen, fourteen, sixteen and nine digits. Incidentally it might be remarked that these mathematicians who could jumble such big numbers with ease and perform mathematical operations with those numbers by means of calculations made on the floor using cowries or using such other simple equipment do deserve kudos even from the mathematicians of today, equipped with sophisticated devices like calculators and computers.

14. *Cf.* the *candra-vākyas* of the Kerala astronomer Vararuci, 348 in number, which give the daily angular motion of the Moon in signs, degrees and minutes. Therein, the expression *gīr naḥ śreyaḥ* represents a particular position of the moon on the zodiac as 12°-03'. Besides, it forms also a logical expression which means 'Our superiority lies in our words'. The expressions in continuation are *dhenavaḥ śrīḥ* (24°-04') 'cows bring prosperity', *rudras tu namyaḥ* (1^r-06°-22'), 'Rudra is to be revered' etc. These are easily memorized, not liable to corruption and in case of any doubt can easily be checked for their correctness through their meaning and grammar.

    For instances of more detailed tables, see the following from the *Candra-vākyas* composed by Saṅgamagrāma-Mādhava (A.D. 1350-1410): *bhāve smaro 'ṅganānām syāt* (10' 03° 25' 44"), *gāyatrī nāstikair nindyā* (10^r 16° 02' 13"), *dhanam coro haren nityam* (10^r 28° 26' 09"), all sensible and easily remembered expressions and, at the same time, expressing the required angular positions of the moon.

15. Among Sanskrit texts written by modern astronomers might be mentioned: *Gaṇitaprakāśikā* by V.A. Poduval, Kannur, Pub.

Desamitram, 1952: *Gaṇitanirṇaya* by Puliyoor Purushottaman Namputiri. Quilon, 2nd edn. 1952; *Śuddha-Dṛggaṇitam* by V.P. Kunjikanna Poduval, Kozhikode, 1956. All the three works have commentaries in Malayalam written by the authors themselves.

16. This work instructs: *sarvatra savarṇā bhāvā rāśayaś ca. na grahāḥ* (1.33-34): 'Everywhere *bhāvas* and *rāśis* are indicated (in this work) by letters, but not so the planets'. For *sūtras* where *Kaṭapayādi* notation is used, see I.4-5 etc. (*Jaiminisūtra*, ed. with tr. By B. Suryanarayana Rao, Bangalore, 1949; ed. with tr. By P.S. Sastri, New Delhi, 1992).

17. S. Madhavan, '*Origin of Kaṭapayādi system of numerals*', *Pūrṇatrayī*, Govt. Sanskrit College, Tripunithura (Kerala), 18. ii (July-Dec. 1991), 35-42.

18. *Sūktaślokāḥ*, ed. With Introduction and Notes by C. Kunhan Raja, *Jl. Of Oriental Research* (Madras), 8 (1935), 358-71.

19. See, for instance, the undermentioned verse by Nārāyaṇa Bhaṭṭa describing the flood in the river Bhāratappuzha in Malabar, each line of the verse depicting the *Kali* date of the flood, alongside describing the gravity of the flood. The poet has also so contrived the letters that the date is given in the normal way in lines one and three and in the reverse way in lines two and four:

    nadīpuṣṭir asahyā nu, nahy asāram payo 'jani /
    nijāt kuṭīrāt sāyāhne, naṣṭārthāḥ prayayur janāḥ //

    The *Kali* date referred to is 17,21,180 which fell in July 1611.

20. For the full list see P. Sambamoorthy, The *Melakartā Janyarāga Scheme*, Madras, ed., pp.14-16; Rangaramanuja Ayyangar, History of South Indian (Carnatic) Music, Madras, 1972, pp.1196-99.

21. Parameśvara states towards the commencement of his work *Dṛggaṇita* (ed. K.V. Sarma, Hoshiarpur, 1963) that computations using the then current *Parahita* system led to the derivation of wrong planetary positions different from what is observed and adds that he was composing his *Dṛggaṇita* according to which computation will tally wit (*Dṛk*. I. i. 2-5) observation. Elsewhere he

has stated that his present effort was the result of 55 years of sky-watching with the instruments. In his *Siddāntadīpikā* (*Mahābhāskarīya-Bhāṣya-vyākhyā*, ed. T.S.K. Sastry, Madras, 1957, p.332, verses 91-93), he gives the then current rate of correction and adds that in course of time even those corrections shall have to be revised.

22. Nīlakaṇṭha Somayāji declares in his work *Jyotirmīmāṃsā*, '*Investigations on Astronomical Theories*' (ed. K.V. Sarma, Hoshiarpur, 1977) that 'the *Karaṇa* texts alone have contemporary value and accuracy: *karaṇānām eva hi vyāvahārikatvam sūkṣmatvam ca syāt* (p. 8) and quotes with approbation other texts: *Karaṇa* is the result of numerous experiments ' *bahuśo yat parīkṣitam karaṇam* ' and a *karaṇa* is one that yields, every day, (computed) results which tally with observation': *dṛṣṭānurūpam karaṇam yad anvaham* (*ibid.*, p.9). In the same work (pp.35-36) Nīlakaṇṭha indicates the principle of experimentation to produce results of computation which would be equal to observation. In another of his works entitled *Grahaparīkṣākrama* he dwells on the methodology of astronomical observation with instruments and the way of finding correct results, of course, towards preparing revised *Karaṇa* texts, which will involve depiction through the *Kaṭapayādi* notation.

23. Jyeṣṭhadeva, author of *Yuktibhāṣā*, '*Elucidation of rationales in Indian astronomy*', (ed., tr. by K.V. Sarma, IIAS. Simla, 2006) makes a mention in the post-colophonic verses of his work *Dṛkkaraṇam* about revising current parameters for computation to equal observation and the necessity of correcting them periodically. 'Interestingly the single palm leaf manuscript of the work (Kerala Univ. Or. Mss. Library, Curator's Collection, Malayalam Sn., No. 7-c) has been written, on three leaves at the close, the sine table of the different planets corrected to the month of *Vṛścika*, Kollam era 1047, corresponding to A.D. 1872, October, in *Kaṭapayādi* notation.

24. For Mss. Catalogued under the titles *'jyāḥ'* and *'Jyotiṣavākhyāni'* in the Kerala Univ. Or. Mss. Librarey, Trivandrum, see its *Alphabetical List of Sanskrit Mss.,* Nos. 5988-99, 6024-36, 25430-34 and 25442-58 in Vols. I and V. See also Index of Malayalam Mss., Nos. 3539-59, 3593.

25. See pp. 135-249, being Appendix III to *Vākyakaraṇa* with the commentary of Sundararāja (eds. T.S.K. Sastry and K. V. Sarma, K.S.R. Institute, Madras, 1962). The *Vākyas* commence as follows: *Kujasya Mahāvākyāni: Parivṛttiḥ* I. *maṅgalaśrīr bhūsūnuḥ* (4^r 23^0 35'), *ātmajayī śantanuḥ* (5^r 18^0 50'), *duṣṭo bhūpatir venaḥ* (6^r 14^0 18') with their *saṃskāra-vākyas* 7, 6 and 4, respectively, indicated by the last letters.

26. Ms. Tanjore Sarasvati Mahal Library, No. 11430. The last three mnemonics are: *dhanyākṣī bālā* (3^0 36'19''), *kamo 'ram bhūmipānām* (15^0 42' 51') and *syād balavān sukhī* (27^0 43' 31')

27. On this, see the commentary of Sūryadeva Yajvan on *Āryabhaṭīya* 1,2 (ed. K.V. Sarma, INSA, New Delhi, 1976, p.10).

28. Parameśvara of Vaṭaśreṇi in Kerala states the system in a simplified manner:

    kādi-makārāntaiḥ syuḥ saṅkhyā ekādikās tu vargasthāḥ /
    yādair avarga-saṃsthāḥ triṃśatpūrvā daśaka-saṅkhyāḥ //
    kādi-yakārādisthaiḥ svarair avarṇādi-saṃjñayā kathitaiḥ /
    vedyaṃ prathamādipadaṃ vargākhyeṣu kramāt, tathānyeṣu //

    (Com. *Siddhāntadīpikā* on Govindasvāmin's *Bhāṣya* on Bhāskara I's *Mahābhāskarīya* 1.8 (ed. T.S. K. Sastry, GOML, Madras, pp.13-14).

29. *Mahāsiddhānta*, ed. By Sudhakara Dvivedi with his own commentary, Banares, 1910; The *Pūrvagaṇita* of Āryabhaṭa's (II) *Mahāsiddhānta*, ed. and tr. By S.R. Sarma. 2 Pts., Marburg, 1966.

30. See, For instance, the depiction of the planetary revolutions:

kalpe sūryādīnām bhagaṇā ghaḍaphenanenanunīnāḥ / mathathamagaglabhananunā khakhajhatajogīpanīnonāḥ // kasadhagasanamaghacasipā bocībhorīkudhitahīrāḥ / sīnararagasakaghaḍaṭhā kaḍhatīmotīdhanīnenāḥ //

(*Mahāsiddhānta*, 1.7-8)

Contrast the above said wording of the numbers with the same numbers given by Nīlakaṇṭha Somayāji in his *Tantrasaṅgraha* in word-numerals for their grace and fluency:
divyābdānāṃ sahasrāṇi dvādaśaikaṃ caturyugam /sūryasya paryāyas, tasmād ayutaghnaradārṅavāḥ / khāśvideveṣu-saptādriśaraś cendoḥ kujasya tu / vedāṅgāhirasāṅkāśvicarā jñasya khaparyayāḥ // nāgavedanabhāḥsaptarāmāṅkasvarabhūmayaḥ / vyomāṣṭarūpavedāṅgapāvakāś ca bṛhaspateḥ // aṣṭāṅgadasranetrāśvikhādrayo bhṛguparyayāḥ / bhāskarāṅga-rasendrāś ca śaneḥ śaśyuccapātayoḥ / netrārkāṣṭāhivedāś ca khakharāmaradāśvinaḥ //

(*Tantrasaṅgraha* of Nīlakaṇṭha Somayāji, 1.15-19a)

Compare also the yuga revolutions set out in *Kaṭapayādi*-I:
nānājñānapragalbhaḥ tilabalamasusūkṣmam, dhayed rājadambho bhadrodanto dharendro, niranusṛgadhisaukhyam, variṣṭho bhiṣaṅgaḥ // dordaṇḍāgredrinātho, viṣamitavipinam, candrarekhāmbukhinne tyarkādeḥ paryayāḥ syuḥ kṣitidinam anṛśaṃsaḥ kalārthī sa martyaḥ //

(*Karaṇapaddhati* of Putumana Somayāji, 1.3).

31. See M.K. Gurukkal, *Kalāvidyā-vivaraṇam* (in Malayalam), Kozhikode, 1937, pp.179-80.
32. *Bhāratīya prācīna Lipimālā*: The Paleography of India (in Hindi), Ajmer, 1918, pp.107-8. See also B.B. Dutta and A.N. Singh, *History of Hindu Mathematics*, Bombay, 1962, pp.72-74.
33. See *Prācīna-Lipimālā*, *op. cit.*, p.7; Burnell, *South Indian Paleography*, London, 1878, p.79.
34. *Prācīna-Lipimālā, op. cit.*, p. 124; Burnell, *op. cit.*, p.79.
35. *Prācīna-Lipimālā*, *op. cit.*, p. 124; Burnell, *op. cit.*, p.79.

APPENDIX I

Bhūtasaṅkhyā System
Word-Numerals in Sanskrit

A. Words for numbers

0. *ananta, antarikṣa, abhra, ambara, ambuda, asat, ākāśa, khaṃ, kha, gagana, chidra, jalada, jaladhara, jaladharapatha, diva, nagna, nabha, payoda, payodhara, puṣkara, pūrṇa, pṛthu, pṛthula, bindu, megha, randhra, varīya, vindu, viyat, viṣṇupada, viṣṇupāda, vihāyas, vṛhat, vyoma, śūnya.*

1. *aṃśumān, acalā, abja, amṛtāṃśu, avani, ādi, āsya, indu, iḷā, uḍupati, urvarā, urvī, ṛkṣeśa, eka, eṇadhara, auṣadhīśa, ka, kalādhara, kali, ku, kumudākarapriya, kṣapākara, kṣamā, kṣiti, kṣoṇī, kṣmā, go, gotra, gotrā, glau, candra, candramā, jagatī, jaivātṛka, jyā, tanu, dākṣāyaṇīprāṇeśa, dharaṇī, dharā, dharitrī, nāyaka, niśākara, niśeśa, pitāmaha, prithivī, pṛthvī, prāleyāṃśu, brahma, bhuvanyu, bhū, bhūmi, mahī, mukha, mṛgalāñchana, mṛgāṅka, medinī, rajanīkara, rajanīśa, rātripa, rātrīśa, rugṇa, rūpa, lapana, vaktra, vadana, vasudhā, vasundharā, vāk, vidhu, viriñci, viśvambharā, śaśadhara, śaśabhṛt, śaśalāñchana, śaśāṅka, śaśi, śaśī, śītakara, śītakiraṇa, śītadyuti, śītamayūkha, śītaraśmi, śītāṃśu, śubhrabhānu, śveta, śvetāṃśu, śitaraśmi, sudhāṃśu, soma, sthirā, hariṇadhṛt, hariṇāṅka, himakara, himagu, himaraśmi, himāṃśu.*

2. *aṃsa, akṣi, antaka, ambaka, ayana, aśvi, aśvinī, īkṣaṇa, oṣṭha, kara, karṇa, kuca, kuṭumba, garut, gulpha. cakṣu, jaṅghā, jānu, dasra, dṛś, dṛṣṭi, doḥ, dvandva, dvaya, dvi, dhruva, naya, nayana, nāsatyau, netra, pakṣa, pāṇi, bāhu, bhuja, bhujā, yama, yamala, yuga, yugala, yugma, ravicandrau, raviputra, locana, śrotra, stana, hasta.*

3. *agni, anala, ājyabjuk, ājyāśa, uṣarbudha, kāla, kṛśānu, kṛṣṇavartma, karma, guṇa, gupti, jagat, jyoti, jvalana, jvāla, tapana, tṛtīya, traya, trikaṭu, trikāla, trigata, triguṇa, trijagat, trinetra, tripadī,*

traita, daha, dahana, dīpti, dyuti, dhāma, netra, pada, pāvaka, puṃ, pura, puruṣa, puṣkara, brahman, bhuvana, ratna, rāma, rudrākṣa, rohita, loka, locana, vacana, vahni, vikrama, viṣṇu, viṣṇukrama, vṛtta, vaiśvānara, śakti, śikhā, śikhin, śivanetra, śūla, saptārci, sahodara, haranayana, haranetra, havyabhuk, havyavāhana, havyāśa, hutabhuj, hutavaha, hutāśa, hutāśana, hotṛ.

4. *apas, abdhi, ambu, ambudhi, ambunidhi, ambhodhi, ambhonidhi, aya, arṇava, āpa, āmnāya, āya, āśrama, udadhi, udanvān, upāya, kaṣāya, kṛta, kendra, koṣṭha, gati, jala, jaladhi, jalanidhi, turīya, turyo, toya, dik, diś, diśā, dhyāna, nadī, nigama, nimnageśa, nīradhi, nīranidhi, payodhi, payonidhi, pātha, pāthodhi, pitāmahāsya, praṇimnageśa, bandha, bandhu, brahmodbhava, mahormi, mahormika, māla, yuga, lavaṇoda, lokapāla, varṇa, vāridhi, vārinidhi, vārdhi, viṣadhi, viṣanidhi, veda, śruti, saṃjñā, samudra, salilākara, sāgara, sukha.*

5. *akṣa, anila, anuttara, artha, asu, āśuga, indriya, iṣu, kaṅkapatrī, karaṇīya, kalaṅka, kāmaguṇa, kāmadeva, khaga, tattva, tanmātra, dhī, nārāca, nālika, pakṣī, pañca, pataṅga, patrin, parva, pavana, pāṇḍava, putra, pṛṣatka, prāṇa, bāṇa, bhāva, bhūta, bhedaka, marut, mahābhūta, mahāvrata, mārgaṇa, ratna, leya, leyaka, vadha, varṣman, vāta, vāyu, viśikha, viṣaya, vrata, śara, śarīra, śāstra, śilīmukha, śuka, śvasana, samiti, sāyaka, smarabāṇa, smareṣu.*

6. *aṅga, abda, arāti, ari, ṛtu, kāya, kāraka, kārtika, kāla, kumāra, kumāravadana, kṛttikā, koṣa, kṣmākhaṇḍa, khara, guhaka, guhavaktra, guhāsya, cakrārdha, camū, caraka, jīva, tarka, darśana, dravya, bhārdha, māsārdha, rasa, rāga, rāsabha, ripu, lekhya, leśyā, varṇa, śakti, śāstra, śilīmukhapada, śiśu, ṣat, ṣaṇmukha, samāsa, senā, skanda, svāda.*

7. *aga, acala, adri, anila, aśva, ṛṣi, kalatra, kulācala, kṣitibhṛt kṣmādhara, kṣmābhṛt, gandhanvaha, gandhavaha, giri, ghoṭā, chanda (chandas), tattva, tāpasa, turaga, turaṅga, divicara, dvīpa, dharaṇīdhara, dharādhara, dharitrīdhara, dhātu, dhī, naga,*

pannaga, parvata, pavana, bhaya, bhūdhara, bhūdhra, bhūbhṛt, marut, mahīdhara, mahīdhra, mātṛkā, māruta, muni, yati, loka, vakrī, vāji, vāta, vāyu, vāra, vāsara, vyasana, śilā, śiloccaya, śaila, sapta, samīra, samīraṇa, sthira, svara, haya.

8. *anīka, anuṣṭubh, ahi, ibha, uraga, karaṭin, karī (karin), kareṇu, karma, (karman) kuñjara, gaja, gahana, gahvara, takṣa, tanu, dantī (dantin), dik, diggaja, diṅnātha, diś. durita, dvipa, dvirada, dhī, dhīguṇa, nāga, nāgendra, padmī, pannaga, pavanabhuk, pīluka, puṣkarin, pradhāna, prabhāvaka, phaṇin, buddhiguṇa, bhadra, bhujaga, bhujaṅga, bhujaṅgama, bhūti, maṅgala, mataṅgaja, mati, mada, mātaṅga, yūthapa, vana, vasu, vāraṇa, viṣabhṛdvapu, vyāla, śriya, sarpa, siddhaguṇa, siddhi, sindhura, suṇḍipa, stamberama, stambherama, hastin.*

9. *aṅka, antara, ambujāsana, upendra, ṛddhi, kapāṭa, kavāṭa, kavi, kūpa, keśava, kṣata, khaga, khacara, khegāmī, khecara, gambhīra, gāmbhīra, go, graha, chidra, tāmiśra, tārkṣyadhvaja, divisad, durgā, dvāra, nanda, nabhoga, nava, nidhāna, nidhi, paṭa, padārtha, bala, bila, miti, yantra, ratna, randhra, labdha, labdhi, vaṭa, vila, vivara, śuṣira, hari.*

10. *aṅguli, aṅgulī avatāra, āśā, kakubh, karma, kāṣṭhā, dik, dikpāla, diś, diśā, paṅkti, rāvaṇaśira, harit.*

11. *akṣauhiṇī, aja, īṣā, īśāna, īśvara, giriśa, girīśa, guṇī, gaurīśa, tryambaka, dhūrjaṭi, paśupati, pinākin, bharga, bhava, mahaḥ, mahādeva, maheśa, maheśvara, mṛḍa, rudra, śaṅkara, śambhu, śarva, śaśibhūṣaṇa, śitikaṇṭha, śiva, śūlin, śrīkaṇṭha, hara.*

12. *arka, āditya, ina, uṣṇāṃśu, gaṇa, cakra, tapana, taraṇi, tigmāṃśu, tīkṣṇāṃśu, dinakara, dinanātha, dinapa, dinamaṇi, dineśa, divākara, dyumaṇi, nara, nā, pataṅga, pūṣā, pradyotana, bhagaṇa, bhānu, bhānumān, bhāskara, maṇḍala, mārtaṇḍa, māsa, mitra, mihira, ravi, rāśi, vivasvān, vyaya, śaṅku, savitā, sūrya, haṃsa.*

13. *aghoṣa, atijagati, anaṅga, karaṇa, kāma, kriyāsthāna, jaya, yakṣa, vandya, viśva, viśve, viśvedevāḥ.*

14. *indra, indraka, kauśika, guṇasthāna, jiṣṇu, purandara, pūrvapa, bhuvana, bhūtagrāma, manu, rajju, loka, vajrin, vāsava, vidyā, śakra, śakvari, śacīpati, surādhipa, sureśa.*

15. *atiśakvarī, ahan, ahnisaṃkhyā, ghasra, tithi, dina, divasa, dyuniśa, pakṣa, paramādhārmika, vāsara, sandhyā.*

16. *avanipa, aṣṭi, indukalā, kalā, kṣmāpa, nṛpa, nṛpati, pṛthvīśa, bhūpa, bhūpati, bhūmipa, ritha, śaśikalā.*

17. *atyaṣṭi, ghaṭā, ghana, jīmūta, toyada, balāha, balāhaka, megha, maitra, valāha, valāhaka, vidhṛti.*

18. *abrahma, tīrtha, dhṛti, pāpasthānaka, purāṇa, vidyā, smṛti.*

19. *atidhṛti, vagha, sāma.*

20. *aṅgula, karaja, kṛti, nakha, nakhara.*

21. *kratu, prakṛti, bṛnda, makha, mūrccha, mūrcchanā, yajña, vṛnda, samidhaḥ, svaḥ, svarga.*

22. *ākṛti, ākṛtī, jāti, jātī, parīṣaha, mati.*

23. *aja, jahu, māyā, meṣa, vikṛti.*

24. *andha, arhat, gāyatrī, jina, tīrthaka, tīrthakṛt, dhamma (dharma), buddha, saṃskṛti, siddha.*

25. *atikṛti, abhikṛti, jṇāna, tattva, puṣṭa.*

26. *atitattva, utkṛti.*

27. *uḍu, ṛkṣa, khadyota, tāra, tāraka, tārakā, tārā, dhiṣṇya, nakṣatra, bha, bhāni.*

28. *ṛkṣa, deha, piṇḍa, hulā.*

29. *āma, uṣṭi, kuva.*

30. *jaṭā, tithi, dina, sādhvī.*

32. *dąnta, daśana, rada, radana.*

33. *amara, asvapna, gīrvāṇa, tridaśa, deva, daivata, nākagha, nirjara, sura.*

39. *dūrvā.*

40. *tāla, paṅkti.*

45. *tripakṣī*

48. *jagati, saṃskāra.*

49. *anila, tāna, pavana, marut, vāyu.*

55. *suṣṭi.*

59. *kāca, mokṣa.*

64. *kalā, yoginī, śrīkalā, strīkalā*

65. *puṣṭi.*

72. *puruṣakalā.*

360. *cakrāṃśa, bhāṃśa.*

5400. *darada*

21600. *cakrakalā, cakraliptā.*

B. Numbers for Words

aṃśa	2
aṃśumān	1
akṣa	5
akṣi	2
akṣauhiṇī	11
aga	7
agni	3
aghoṣa	13
aṅka	9
aṅga	6
aṅgula	20
aṅguli or *aṅgulī*	10
acala	7
acalā	1
aja	11,23
atikṛti	25
atijagatī	13
atitattva	26
atidhṛti	19
atiśakvarī	15
atyaṣṭi	17
adri	7
anaṅga	13
ananta	0
anala	3
anila	5,7,49
anīka	8
anuttara	5
anuṣṭubh	8
antaka	2
antara	9
antarikṣa	0
andha	24
apas	4
abja	1
abda	6
abdhi	4
abrahma	18
abhikṛti	25
abhra	0
amara	33
amṛtāṃśu	1
ambaka	2
ambara	0
ambu	4
ambujāsana	9
ambuda	0
ambudhi	4
ambunidhi	4
ambodhi	4
ambhonidhi	4
aya	4
ayana	2
arāti	6
ari	6
arka	12
arṇava	4
artha	5
arhat	24
avatāra	10
avani	1
avanipa	16
aśva	7
aśvi	2
aśvinī	2
aṣṭi	16
asat	0
asu	5
asvapna	33
ahan	15
ahi	8
ahnisaṃkhyā	15
ākāśa	0
ākṛti	22
ākṛtī	22
ājyabhuk	3
ājyāśa	3
ādi	1
āditya	12
āpa	4
āma	29
āmnāya	4
āya	4
āśā	4
āśuga	5
āśrama	4
āsya	1
ina	12
indu	1
indukalā	16
indra	14
indraka	14
indriya	5
ibha	8
ilā	1
iṣu	5

īkṣaṇa	2
īśa	11
īśāna	11
īśvara	11
uḍu	27
uḍupati	1
utkṛti	26
udadhi	4
udanvān	4
upāya	4
upendra	9
uraga	8
urvarā	1
urvī	1
uṣarbudha	3
uṣṭi	29
uṣṇāṃśu	12
ṛkṣa	27,28
ṛkṣeśa	1
ṛtu	6
ṛddhi	9
ṛṣi	7
eka	1
eṇadhara	1
oṣṭha	2
auṣadhīśa	1
ka	1
kakubh	10
kaṅkapatri	5
kapāṭa	9
kara	9
karaja	20
karaṭin	8
karaṇa	13
karaṇīya	5
karī (karin)	8
kareṇu	8
karṇa	2
karma(karman)	8,10
kalaṅka	5
kalatra	7
kalā	16,64
kalādhara	1
kali	1
kavāṭa	9
kavi	9
kaṣāya	4
kāca	59
kāma	13
kāmaguṇa	5
kāmadeva	5
kāya	6
kāraka	6
kārtika	6
kāla	3,6
kāṣṭha	10
kāṣṭhā	10
ku	1
kuca	2
kuñjara	8
kuṭumba	2
kumāra	6
kumāravadana	6
kumudākarapriya	1
kulācala	7
kuva	29
kūpa	9
kṛta	4
kṛti	20
kṛttikā	6
kṛśānu	3
kṛṣṇavartma	3
kendra	4
keśava	9
koṣa	6
koṣṭha	4
kauśika	14
kratu	21
krama	3
kriyāsthāna	13
kṣata	9
kṣapākara	1
kṣamā	1
kṣiti	1
kṣitibhṛt	7
kṣoṇi	1
kṣoṇī	1
kṣmā	1
kṣmākhaṇḍa	6
kṣmādhara	7
kṣmāpa	16
kṣmābhṛt	7
kham	0
kha	0
khaga	5,9
khacara	9
khadyota	27
khara	6
khegāmī	9

khecara	9	*ghoṭā*	7	*jyā*	1
gagana	0	*cakra*	12	*jyoti*	3
gaja	8	*cakrakalā*	21600	*jñāna*	25
gaṇa (bhagaṇa)	12	*cakraliptā*	21600	*jvalana*	3
gati	4	*cakrāṃśa*	360	*jvāla*	3
gandhanvaha	7	*cakrārdha*	6	*takṣa*	8
gandhavaha	7	*cakṣu*	2	*tattva*	5,7,25
gambhīra	9	*candra*	1	*tanu*	1,8
garut	2	*candramā*	1	*tanmātra*	5
gahana	8	*camū*	6	*tapana*	3,12
gahvara	8	*caraka*	6	*taraṇi*	12
gāmbhīra	9	*chanda (chandas)*	7	*tarka*	6
gāyatrī	24	*chidra*	0,9	*tāna*	49
giri	7	*jagat*	3	*tāpasa*	7
giriśa	11	*jagatī*	1,48	*tāmisra*	9
girīśa	11	*jaṅghā*	2	*tāra* or *tāraka*	27
gīrvāṇa	33	*jaṭā*	30	*tārakā*	27
guṇa	3	*jaya*	13	*tārā*	27
guṇasthāna	14	*jala*	4	*tārkṣyadhvaja*	9
guṇī	11	*jalada*	0	*tāla*	40
gupti	3	*jaladhara*	0	*tigmāṃśu*	12
gulpha	2	*jaladharapatha*	0	*tithi*	15,30
guhaka	2	*jaladhi*	4	*tīkṣṇāṃśu*	12
guhavaktra	6	*jalanidhi*	4	*tīrtha*	18
guhāsya	6	*jahu*	23	*tīrthaka*	24
go	1,9	*jāti*	22	*tīrthakṛt*	24
gotra	1	*jātī*	22	*turaga*	7
gotrā	1	*jānu*	2	*turaṅga*	7
gaurīśa	11	*jina*	24	*turīya*	4
glau	1	*jiṣṇu*	14	*turya*	4
graha	9	*jīmūta*	17	*tṛtīya*	3
ghaṭā	17	*jīva*	6	*toya*	4
ghana	17	*jaivātṛka*	1	*toyada*	17
ghasra	15			*traya*	3

trikaṭu	3	*divicara*	7	*dhāma*	3
trikāla	3	*divisad*	9	*dhiṣṇya*	27
trigata	3	*diś*	4,8,10	*dhīguṇa*	8
triguṇa	3	*diśā*	4,8,10	*dhūrjaṭi*	11
trijagat	3	*dīpti*	3	*dhṛti*	18
triadaśa	33	*durita*	8	*dhyāna*	4
trinetra	3	*durgā*	9	*dhruva*	2
tripakṣī	45	*dūrvā*	39	*nakṣatra*	27
tripadī	3	*dṛś*	2	*nakha*	20
traita	3	*dṛṣṭi*	2	*nakhara*	20
tryambaka	11	*deva*	33	*naga*	7
danta	32	*deha*	28	*nagna*	0
dantī (dantin)	8	*daivata*	33	*nadī*	4
darada	5400	*doḥ*	2	*nanda*	9
darśana	6	*dyuti*	3	*nabha(nabhas)*	0
daśana	32	*dyuniśā*	15	*nabhoga*	9
dasra	2	*dyumaṇi*	12	*naya*	2
daha	3	*dravya*	6	*nayana*	2
dahana	3	*dvandva*	2	*nara*	12
dākṣāyaṇīprāṇeśa	1	*dvaya*	2	*nava*	9
dik	4,8,10	*dvāra*	9	*nā*	12
dikpāla	10	*dvi*	2	*nākagṛha*	33
diggaja	8	*dvipa*	8	*nāga*	8
diṅnātha	8	*dvirada*	8	*nāgendra*	8
dina	15,30	*dvīpa*	7	*nāyaka*	1
dinakara	12	*dharaṇīdhara*	7	*nārāca*	5
dinanātha	12	*dharaṇī*	1	*nālika*	5
dinapa	12	*dharā*	1	*nāsatyau*	2
dinamaṇi	12	*dharādhara*	1	*nigama*	4
dineśa	12	*dharitrī*	1	*nidhāna*	9
diva	0	*dharitrīdhara*	7	*nidhi*	9
divasa	15	*dhamma (dharma)*	24	*nimnageśa*	4
divākara	12	*dhātu*	7	*nirjara*	33

niśākara	1
niśeṣa	1
nīradhi	4
nīranidhi	4
nṛpa	16
nṛpati	16
netra	2,3
pakṣa	2,15
pakṣi	5
paṅkti	10,40
pañca	5
paṭa	9
pataṅga	5,12
patrin	5
pada	3
padārtha	9
padmī	8
pannaga	7,8
payoda	0
payodhara	0
payodhi	4
payonidhi	4
paramādhārmika	15
parīṣaha	22
parva	5
parvata	7
pavana	5,7,49
pavanabhuk	8
paśupati	11
pāṇi	2
pāṇḍava	5
pātha	4
pāthodhi	4
pāpasthānaka	18
pāvaka	3
piṇḍa	28
pitāmaha	1
pitāmahāsya	4
pinākin	11
pīluka	8
puṃ	3
putra	5
pura	3
purandara	14
purāṇa	18
puruṣa	3
puruṣakalā	72
puṣkara	0,3
puṣkarin(-hastin)	8
puṣṭa	25
puṣṭi	65
pūrṇa	0
pūrvapa	14
pūṣā(pūṣan)	12
pṛthivī	1
pṛthu	0
pṛthula	0
pṛthvī	1
pṛthvīśa	6
pṛṣatka	5
prakṛti	21
praṇimnageśa	4
pradyotana	12
pradhāna	8
prabhāvaka	8
prāṇa	5
prāleyāṃśu	1
phaṇin	8
bandha	4
bandhu	4
bala	9
balāha	17
balāhaka	17
bāṇa	5
bāhu	2
bindu	0
bila	9
buddha	24
buddhiguṇa	8
bṛnda	21
brahman	3
brahmā	1
brahmodbhava	4
bha	27
bhagaṇa	12
bhadra	8
bhaya	7
bharga	11
bhava	11
bhāṃśa	360
bhāni	27
bhānu	12
bhānumān	12
bhārdha	6
bhāva	5
bhāskara	12
bhuja	2
bhujaga	8
bhujaṅga	8

bhujaṅgama	8
bhujā	2
bhuvana	3,14
bhuvanyu	1
bhū	1
bhūta	5
bhūtagrāma	14
bhūti	8
bhūdhara	7
bhūdhra	7
bhūpa	16
bhūpati	16
bhūbhṛt	7
bhūmi	1
bhūmipa	16
bhedaka	5
makha	21
maṅgala	8
maṇḍala	12
mataṅgaja	8
mati	8,22
mada	8
manu	14
marut	5,7,49
mahaḥ	11
mahādeva	11
mahābhūta	5
mahāvrata	5
mahī	1
mahīdhara	7
mahīdhra	7
maheśa	11
maheśvara	11
mahormi	4
mahormika	4
mātaṅga	8
mātṛkā	7
māyā	23
māruta	7
mārgaṇa	5
mārtā(rta)ṇḍa	12
māla	4
māsa	12
māsārdha	6
miti	9
mitra	12
mihira	12
mukha	1
muni	7
mūrcchā	21
mūrcchanā	21
mṛgalāñchana	1
mṛgāṅka	1
mṛḍa	11
megha	17
medinī	1
meṣa	23
maitra	17
mokṣa	59
yakṣa	13
yajña	21
yati	7
yantra	9
yama	2
yamala	2
yuga	2,4
yugala	2
yugma	2
yūthapa	8
yoginī	64
rajanīkara	1
rajanīśa	1
rajju	14
ratna	3,5,9
rada	32
radana	32
randhra	0,9
ravi	12
ravichandrau	2
raviputra (yama)	2
rasa	6
rāga	6
rātripa	1
rātrīśa	1
rāma	3
rāvaṇaśira	10
rāśi	12
rāsabha	6
ritha	16
ripu	6
rugṇa	1
rudra	11
rudrākṣa	3
rūpa	1
rohita (rohitāśva)	3
lapana	1
labdha	9
labdhi	9
lavaṇoda	4

lekhya	6
leya	5
leyaka	5
leśyā	6
loka	3,7,14
lokapāla	4
locana	2,3
vaktra	1
vakrī	7
vacana	3
vajrin	14
vaṭa	9
vadana	1
vadha	5
vana	8
vandya	13
varīya	0
varṇa	4,6
varṣman	5
valāha	17
valāhaka	17
vasu	8
vasudhā	1
vasundharā	1
vahni	3
vāk	1
vāji	7
vāta	5,7,49
vāyu	5,7,49
vāra	7
vāraṇa	8
vāridhi	4
vārinidhi	4
vāsara	7,15
vāsava	14
vikṛti	23
vikrama	3
vidyā	14,18
vidhu	1
vidhṛti	17
vindu	0
viyat	0
viriñci	1
vila	9
vivara	9
vivasvān	12
viśikha	5
viśva	13
viśvambharā	1
viśve	13
viśvedevāḥ	13
viṣadhi	4
viṣanidhi	4
viṣabhṛdvapu	8
viṣaya	5
viṣṇu	3
viṣṇukrama	3
viṣṇupada	0
viṣṇupāda	0
vihāyas	0
vṛtta	3
vṛnda	21
vṛhat	0
veda	4
vaiśvānara	3
vyaya	12
vyasana	7
vyāla	8
vyoma	0
vrata	5
śakti	3,6
śakra	14
śakvarī	14
śaṅkara	11
śaṅku	12
śacīpati	14
śambhu	11
śara	5
śarīra	5
śarva	11
śaśadhara	1
śaśabhṛt	1
śaśalāñchana	1
śaśāṅka	1
śaśi	1
śaśī	1
śaśikalā	16
śaśibhūṣaṇa	11
śastra	5
śāstra	6
śikhā	3
śikhin	3
śitikaṇṭha	11
śilā	7
śilīmukha	5
śilīmukhapada	6
śiloccaya	7
śiva	11
śivanetra	3

śiśu	6	*samidhaḥ*	21	*smarabāṇa*	5
śītakara	1	*samīra*	5,7,49	*smareṣu*	5
śītakiraṇa	1	*samīraṇa*	5,7,49	*smṛti*	18
śītadyuti	1	*samudra*	4	*strīkalā*	64
śītamayūkha	1	*sarpa*	8	*svaḥ*	21
śītaraśmī	1	*salilākara*	4	*svara*	7
śītāṃśu	1	*savitā*	12	*svarga*	21
śuka	5	*sahodara*	3	*svāda*	6
śubhrabhānu	1	*sāgara*	4,7	*haṃsa*	12
śuṣīra	9	*sādhvī*	30	*haya*	7
śūnya	0	*sāma*	19	*hara*	11
śūla	3	*sāyaka*	5	*haranayana*	3
śūlin	11	*sitaraśmī*	1	*haranetra*	3
śaila	7	*siddha*	24	*hari*	9
śriya	8	*siddhii*	8	*hariṇadhṛt*	1
śrī	8	*sindura*	8	*hariṇāṅka*	1
śrīkaṇṭha	11	*sukha*	4	*harit*	10
śrīkalā	64	*suṇḍipa*	8	*havyabhuk*	3
śruti	4	*sudhāṃśu*	1	*havyavāhana*	3
śrotra	2	*sura*	33	*havyāśa*	3
śvasana	5	*surādhipa*	14	*hasta*	2
śveta	1	*sureśa*	14	*hastin*	8
śvetāṃśu	1	*suṣira*	9	*haṃsa*	8
ṣaṭ	6	*suṣṭi*	55	*himakara*	1
ṣaṇmukha	6	*sūrya*	12	*himagu*	1
Saṃskāra	48	*senā*	6	*himaraśmi*	1
saṅkṛti	24	*soma*	1	*himāṃśu*	1
sañjā	4	*skanda*	6	*hutavaha*	3
sandhyā	15	*stana*	2	*hutabhuj*	3
sapta	7	*stamberama*	8	*hutāśa*	3
saptārci	3	*stambherama*	8	*hutāśana*	3
samāsa	6	*sthira*	7	*hulā*	28
samiti	5	*sthirā*	1	*hotṛ*	3

APPENDIX II

Numbering of the Pages/Folios of the Manuscripts

The numbering of the pages of a Manuscript is done on each leaf not on each page. The two pages (sides) of a leaf have only one mark, placed on the first page.

The first leaf of a book is marked with the letter *ka,* the second with *kā* etc. The 34 consonants of the Sanskrit alphabet, combining with the 14 vowels, the *anusvāra* and the *visarga,* make a total of 544 signs. A consonant with the *anusvāra* is written as *kāṃ, khāṃ* etc. Where the number of leaves in a book exceeds 544, as in the *Samantapāsādikā* and the *Jātaka aṭṭakathā* of this collection, the numbering recommences with *ka* but with the number 2 in front. Thus for instance, 2 *kā* denotes 544 + 6 = 550 and 2 no. denotes 544 + 77= 621.

A table giving full details for the deciphering of the number of a leaf is given below for ready reference (from Adikaram, E.W. *Descriptive Calalogue of the Pāli Manuscripts in the Adyar Library.* The Adyar Library, Madras, 1947, pp. xv-xvi).

NUMBERING OF THE FOLIOS OF A MANUSCRIPT

	a	ā	i	ī	u	ū	ṛ	ṝ	ḷ	ḹ	e	ai	o	au	aṃ	aḥ
	ka	kā	ki	kī	ku	kū	kṛ	kṝ	kḷ	kḹ	ke	kai	ko	kau	kaṃ	kaḥ
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
kha	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
ga	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
gha	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
ṅa	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
ca	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
cha	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112
ja	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128
jha	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144
ña	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
ṭa	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176
ṭha	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192
ḍa	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208
ḍha	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224
ṇa	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240
ta	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256
tha	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272
da	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288
dha	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304
na	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320
pa	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336
pha	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352
ba	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368
bha	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384
ma	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400
ya	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416
ra	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432
la	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448
va	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464
śa	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480
ṣa	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496
sa	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512
ha	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528
ḷa	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544
		ḷā	ḷi	ḷī	ḷu	ḷū	ḷṛ	ḷṝ	ḷḷ	ḷḹ	ḷe	ḷai	ḷo	ḷau	ḷi	ḷaḥ

ĀRYABHAṬA :

HIS NAME, TIME AND PROVENANCE*

Introductory :

Āryabhaṭa is one of the eminent astronomers of early India. Of late there is a tendency to spell his name as 'Āryabhaṭṭa'. While Āryabhaṭa himself mentions *Kali* 3600 is the date of his composing the work, some say that *Kali* 3600 is the date of his birth. A view has been broached that Āryabhaṭa hailed from Kerala. These points have been discussed and an effort has been made here to arrive at the correct position in these matters.

Key words: Āryabhaṭa, Aśmaka, Kusumapura, Pāṭaliputra.

Āryabhaṭa is acknowledged as one of the astute astronomers of early India. His school of astronomy is well known and widespread all over India, especially in the South. However, differing voices are heard about his name, date and provenance.

I.The name of the astronomer is Āryabhaṭṭa or Āryabhaṭa?

Of late, there has been a tendency to spell the name as 'Āryabhaṭṭa' with the suffix 'bhaṭṭa'. Two artificial satellites sent up into space by Indian scientists are given the names 'Āryabhaṭṭa I' and 'Āryabhaṭṭa II'. Some modern writers also make use of this spelling. But, is the spelling of the astronomer's name with the suffix 'bhaṭṭa' correct?

Now, it is to be noted that no astronomical text spells the name as 'Āryabhaṭṭa'. The author himself mentions his name at three places only as 'Āryabhaṭa', towards the beginning and ending verses of his work *Āryabhaṭīya.*[1]

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praṇipatyaikam anekam kam satyām devatām param brahma ı
āryabhaṭas *triṇi gadati gaṇitaṃ kālakriyāṃ golam* ıı
(*Āryabhaṭīya, Gītikāpāda,* Verse 1)

brahma-ku-śaśi-budha-bhṛgu-ravi-kuja-guru-koṇa-bhagaṇān namaskṛtya ı
āryabhaṭas *tv iha nigadati kusumapure 'bhyarcitaṃ jñānam* ıı
(*Gaṇitapāda,* Verse 1)

āryabhaṭīyaṃ nāmnā pūrvaṃ svāyaṃbhuvaṃ sadā nityam ı
sukṛtāyuṣoḥ praṇāśaṃ kurute pratikañcukaṃ yo' sya ıı
(*Golapāda,* Verse 50)

Our author's younger contemporary, Varāhamihira, too, mentions the name only as Āryabhaṭa and that too in a verse, which forecloses the form 'Āryabhaṭṭa'. Thus, while speaking of the two ways of reckoning the day, viz., from midnight and from sunrise, propounded by our author, Varāhamihira says in his *Pañcasiddhāntikā* (XV. 20) :

Laṅkārdharātrasamaye dinapravṛttiṃ jagāda cāryabhaṭaḥ ı
bhūyaḥ sa eva sūryodayāt prabhṛty āha laṅkāyām ıı

In his commentary on *Āryabhaṭīya,* Bhāskara I, an ardent follower of our author, mentions the author's name only as Āryabhaṭa whenever the latter is mentioned during the course of the commentary. The concluding verse of the commentary too mentions the name only as Āryabhaṭa:[2]

atīndriyārthapratipādakāni sūtrāṇy amūny āryabhaṭoditāni ı
teṣām aśakyo 'rthaśatāṃśako 'pi vaktum kuto 'smatsadṛśair aśeṣam ı

Brahmagupta (6th cent. AD), contemporary of Bhāskara I, mentions Āryabhaṭa at the beginning verse of his *Khaṇḍakhādyaka* (1.11)

praṇipatya mahādevaṃ jagadutpattisthitipralayahetum ı
vakṣyāmi khaṇḍakhādyakam ācāryāryabhaṭatulyaphalam ıı

Someśvara, another early commentator (c. 1000 AD) on the *Āryabhaṭīya,* too spells the name of our author only as Āryabhaṭa in the concluding verse of his commentary:

spaṣṭārthapratibodhakaṃ mṛdudhiyāṃ sūktaṃ
prabodhapradaṃ
tarkavyākaraṇādiśuddhamatinā someśvareṇādhunā ।
ācāryāryabhaṭokta sūtravivṛtir yā bhāskarotpāditā
tasyāḥ sārataraṃ vikṛṣya racitaṃ bhāṣyaṃ prakṛṣṭaṃ laghu ॥
(Com. on *Golapāda,* Verse 50)

In the same vein Sūryadeva Yajvan (c. 1000 AD), hailing from Tamilnadu, discloses his commentary on *Āryabhaṭīya* with the verse.

triskandhārthavidā samyak sūryadevena yajvanā ।
saṅkṣipyāryabhaṭaproktasūtrārtho 'tra prakāśyate ॥
(Com. Sūryadeva *Upodghāta,* Verse 3)

Śaṅkaranārāyaṇa, the court-astronomer of the Kerala King Ravivarma of the 8th century, commences his commentary of the *Laghubhāskarīya* of Bhāskara I with the verse:

ācāryāryabhaṭaṃ varāhamihiraṃ
śrīmadguruṃ bhāskaram ।
govindaṃ haridattam atra śirasā
vakṣye praṇamya kramāt ॥
(Maṅgalaśloka 2)

Gārgya-Kerala-Nīlakaṇṭha Somayāji commences his commentary on the *Āryabhaṭīya* with the verse:

bhagavantaṃ cāryabhaṭaṃ
natvā vyākhyāyate 'tha tat tantram /

The Kerala commentator Ghaṭīgopa's commentary commences with the verse:

gajānanaṃ ca vāṇīṃ ca śrī-sūryādīn grahān api ।
pūrvācāryāṃś cāryabhaṭapramukhān praṇato 'smy aham ॥

It is to be noted that in all the above cases the name of our author is spelt only as 'Āryabhaṭa' and not 'Āryabhaṭṭa' and that the latter form will revolt against the metre.

It should be obvious from the above that the correct name of our author only 'Āryabhaṭa' and that the modern tendency to revise the name to 'Āryabhaṭṭa' is not warranted.

II. Date of Āryabhaṭa

Propritiously enough, Āryabhaṭa himself gives a clue to his date in his *Āryabhaṭīya, Kālakriyāpāda,* verse 10, which reads:

ṣaṣṭyabdānāṃ ṣaṣṭir yadā vyatītās trayaś ca yugapādāḥ ।
tryadhikā viṃśatir abdās tadeha mama janmano 'tītāḥ ॥

'When sixty times sixty years and three quarter *Yugas* (of the current *yuga*) had elapsed, twenty three years had then passed since my birth.'

The stanza states that at the time of composing the work 60 x 60 = 3600 years of the *Kaliyuga* had elapsed and, incidentally, the author adds that it was then 23 years after his birth. The date works out to the end of the *Kali* year 3600, corresponding to the *Śaka* year 421, the date being March 21, 499. The position of the equinoxes were then zero degree and so the mean positions of the planets would be accurate if computed using their parameters given by the author in the *Gītikāpāda* of the *Āryabhaṭīya.*[3] For computation of the mean planetary positions for future dates, a small correction was to be applied, which Āryabhaṭa's follower Lallācārya gives in his work *Śiṣyadhīvṛddhida.*[4]

While most commentators follow the above interpretation, in Kerala, the *Parahita* system enunciated by Haridatta in 689 A.D. interprets the verse to mean that the date given in the verse is the date of birth of Āryabhaṭa and not the date of the composition of the work.

"When sixty times sixty years and three *Yugas* had elapsed, twenty three years of my age have passed since then."

This would mean that Āryabhaṭa was born in *Kali* 3600, equivalent to *Śaka* 421 or AD 499, and that he composed the *Āryabhaṭīya* when he was 25 years old, i. e. in *Śaka* 444 or AD. 522. But the parameters of *Āryabhaṭīya* accord only with the year *Kali* 3600. For this reason, in the *Parahita* system corrections for computing the mean longitudes of planets using Āryabhaṭa's parameters but with the epoch of *Śaka* 444 have been evolved for use in astronomical computations.[5]

III. *AŚMAKA* : Āryabhaṭa's Provenance

Āryabhaṭa does not make any specific mention of the place or country of his birth but this omission is filled by Bhāskara I, his follower and commentator, who is, perhaps, the best authority in the matter on account of his chronological proximity, besides being the propagator of the *Āryabhaṭīya* school.

Bhāskara I who hailed from southern Gujarat, as evidenced from references in his commentary on the *Āryabhaṭīya*, calls himself as *Āśmakīya, 'one beloging to the Aśmaka* country'. He also specifies that Āryabhaṭa too was an *Āśmakīya,* for which reason his work was called *Aśmakatantra.* Nīlakaṇṭha Somayāji states specifically in his commentary on *Āryabhaṭīya (Gaṇitapāda, verse* 1) : *Aśmaka-janapadajāta Āryabhaṭācāryaḥ,* 'Āryabhaṭa born in the *Aśmaka* country.'

The *Aśmaka* country was situated, according to Varāhamihira (*Bṛhatasaṃhitā*, XIV. 22), the *Rāmāyaṇa* and the *Mahābhārata,* in the North- West of India. According to the Buddhist text *Dīghanikāya* (XIX. 36), during the time of the Buddha a branch of the *Aśmaka* people moved to the South and settled in the modern South Gujarat-North Maharastra region, on the banks of the rivers Godāvarī and Narmadā. Several texts, both Buddhist and Hindu, attest to this fact. Obviously, Āryabhaṭa hailed from this region and naturally came to be known as *Āśmakīya*.[6]

Of late, a quaint suggestion has been made to the effect that Kerala could have been the country of birth of Āryabhaṭa for two reasons. The first one is that the word *Aśmaka,* which, in Sanskrit, means 'stone', could be related to Koṭuṅṅallūr in Central Kerala, which during early times, was one of the capital cities of the land and a center of learning. It is stated that its present name could be a derivative of the work *Koṭum-kal-l-ūr*, meaning 'a city of hard stones', since in Malayalam *koṭu* means hard and *kal* means stone. This is linguistically possible, but the incompatibility arises from the fact that old records show that, during ancient times, the city was known as *Koṭum-kol-ūr*, 'the city of strict governance'. Naturally enough, the harsher pronouncing word *Koṭum-kol-ūr* slipped into the more easily pronounced word Koṭuṅṅallūr. That the said ancient name of the city occurs in certain early texts has been noticed by the veteran litterateur and researcher, the late Ulloor S. Parameswara Aiyer, in his article '*Kuṇavāyirkoṭṭam and Vañci*', (K. V. *Rangaswami Aiyangar Commemoration Volume*, Madras, 1940, pp. 241-51). Idenitifying this with *Vañci*, the capital of the Cera kings of Kerala, he quotes two passages from early texts wherein the name of the city is spelt only as Kotumkolūr and not Koṭumkallūr. Quoting from a 12-13th century Sanskrit-Tamil work in *Maṇipravāḷam* style he states:

> *kollavibhṛtim kollum vibhavā nūru maṭaṅṅu 'koṭumkolūrilum' ere viḷaṅṅina paṅṭupayātā kuṇavāyakkuṅtram api kuṇapam dadhati* ।

'It will be seen that the author begins from the south, and touches Kollam (present-day Quilon), Koṭuṅṅolur (Koṭumkolūr, the modern Koṭuṅṅallūr, whose anglicized form is Cranganore), Kuṇavāy etc.'(p. 242).

Later in the same article (p. 246) he refers to the occurrence of the name of the city, again, as Koṭuṅkolūr. Further he refers to the early Tamil classic *Cilappatikāram* and quotes from Aṭiyākkunallār, the commentator of the classic: '*Kunram, Koṭuṅkolūrkku ayalatākiya Ceṅkunrenum malai*' (p. 246, fn. 13).

It should be amply clear from the above-given references that during the time of Āryabhaṭa (*c.* AD 500), which is the time also of *Cilappatikāram,* and, later too, the city was known only as Koṭumkolūr ('the city of stern rule') and not Koṭumkallūr ('the city of hard stones'), to give it any possibility of being equated with *Aśmaka*.

The non-feasibility of Kerala being the *Aśmaka* region is strengthened by the fact that nowhere in the two works of Āryabhaṭa, viz., *Āryabhaṭīya* and the *Āryabhaṭasiddhānta*, Kerala has been referred to. More telling is the fact that Āryabhaṭa has concocted an extremely inconvenient system of letter-numerals, which he would not have done, had he been aware of the facile letter- numeral systems of *Kaṭapayādi* which was prevalent in Kerala even before the time of Āryabhaṭa. It might also be noted that even the names of the three known disciples of Āryabhaṭa, Pāṇḍuraṅgasvāmi, Niśaṅku and Lāṭadeva do not have any semblance of Keralite personal names, old or new.

Equally fragile is the second reason adduced, viz., that Āryabhaṭa should have hailed from Kerala since, besides the Āryabhaṭan system being prevalent in this land, 'all' commentaries on *Āryabhaṭīya* have been produced by Kerala astronomers. This argument really does not stand scrutiny. For one thing, though the *Āryabhaṭīya* and works on its basis are widely prevalent in Kerala, the second work of Āryabhaṭa, viz., *Āryabhaṭasiddhānta* is not known in Kerala at all. The prevalence of *Āryabhaṭīya* also outside Kerala is vouched by the fact of its being studied and commentaries thereof produced elsewhere as well, both in Sanskrit and in the regional languages. Among the non-Keralite commentators and commentaries and works based on the *Āryabhaṭīya* the following may be mentioned.[7]

Non-Keralite Commentators in Sanskrit

1. Prabhākara (c. 525 A.D.)
2. Bhāskara I (629 A.D.) of Valabhī in Gujarat.
3. Someśvara (c.968-1200) of Gujarat
4. Sūryadeva Yajvan (1191 A.D.) of Gaṅgaikoṇḍa-colapuram in Tamilnadu.

5. Yallaya (fl.1482) of Skandasomeśvara in Telugu country.
6. Raghunātharāja (1597) of Ahobilam in Karnataka.
7. Mādhava, son of Virūpākṣa of Andhra Pradesh.
8. Bhūtiviṣṇu, son of Devarāja, of Kāñcīpuram in Tamilnadu.
9. Kodaṇḍarāma (1807-93) of Andhra Pradesh.

Commentators in Telugu

10. Virūpākṣa Sūri of Andhra Pradesh.
11. Kodaṇḍarāma (1807-93) of Andhra Pradesh who wrote a commentary in Sanskrit also.

Commentator/Translator in Marathi

12. Anonymous Ms. in the Bombay University Library, No.334.

Works produced outside Kerala, based on Āryabhaṭīya

13. Bhāskara I, *Mahābhāskarīya*
14. Bhāskara I, *Laghubhāskarīya*
15. Lalla, *Śiṣyadhīvṛddhida*
16. Brahmadeva (1092 AD), *Karaṇaprakāśa*
17. Dāmodara (1400 AD), *Bhaṭatulya*
18. Vīrasiṃhagaṇaka, son of Kāśīrāja, *Āryasiddhānta-tulya-karaṇa*

Translator in Arabic

19. Abul Hasan Ahwazi under the Caliphate in Baghdad.

It is also to be noted that the second work of Āryabhaṭa, viz., *Āryasiddhānta*, is completely unknown in Kerala while it has influenced astronomical writings in Andhra Pradesh, Northwest India, Iran and the early Abbasid Caliphate.

In view of the above massive evidence, any claim that the study of *Āryabhaṭīya* was carried on and that commentaries were written only in Kerala, and therefore Āryabhaṭa hailed from Kerala, loses all credibility.

Kusumapura where Āryabhaṭa flourished

Āryabhaṭa states in the *Āryabhaṭīya* (*Gaṇitapāda*, verse 1) that he was setting forth in his work the knowledge that had been honoured in Kusumapura. The following verse specifies that at a time when the results computed through the then prevailing five astronomical schools (*Siddhāntas*) (viz., *Vāsiṣṭha, Paitāmaha, Paulīśa, Romaka* and *Saura* gave conflicting results, Āryabhaṭa, as the head of an institution (*kulapa*), set forth his modified system of astronomical computation in Kusumapura:

> *siddhānta-pañcakavidhāv api dṛgviruddha-*
> *mauḍhyoparāgamukha-khecaracāraklṛptau* ।
> *sūryaḥ svayam kusumapury abhavad kalau tu*
> *bhūgolavit kulapa āryabhaṭābhidhānaḥ* ॥

'When the methods of the five *Siddhāntas* began to yield results conflicting with the observed results as in the case of setting of the planets, eclipses etc., there appeared in the *Kali* age, at Kusumapura, God Sun himself in the form of Āryabhaṭa, the *Kulapa* ('head of an institution') well versed in astronomy.'

In spite of the well-known identification of Kusumapura with Pāṭaliputra (modern Patna), the capital of the ancient Magadha country (Bihar), suggestions have been hazarded that if the *Aśmaka* country could be identified as Kerala, Kusumapura can be identified with the township of Pūṅkunnam near Trichur and if *Aśmaka* could be the same as Tamilnadu, Kusumapura can be identified with Pūmpuhār on the east coast. The puerile nature and far-fetchedness of both these suggestions would be obvious when it is noted that they do not conform even to the literal meaning of Kusumapura, 'flower city', since the two suggested words mean only 'flower hill' and 'flower river-mouth'. There is neither an astronomical tradition nor such an institution in these two places, to sustain the epithet of *Kulapa* given to Āryabhaṭa.

Indian tradition, Hindu and Buddhists, Purāṇic and Historical, is loud and clear in identifying Kusumapura with Pāṭaliputra, the capital

of Magadha[8]. In fact, Āryabhaṭa's follower Bhāskara-I himself states in his commentary on the *Āryabhaṭīya* that Kusumapura is Pāṭaliputra. Thus, in his commentary on *Āryabhaṭīya* (*Gaṇitapāda*, verse 1), he explains '*Kusumapure 'bhyacaritam jñānam. Kusumapuram Pāṭaliputram.*' The Sanskrit lexicons offer also alternate forms for both the names, viz., *Kusumapura* in Hemacandra's *Abhidhānacintāmaṇi* (133.976) and *Puṣpapura* in Keśava's *Kalpadrukośa* (10.18), *Pāṭaliputra* in the *Abhidhānacintāmaṇi* (133.976), *Pāṭaliputraka* in Puruṣottama's *Trikāṇḍaśeṣa* and *Pura* in Hemacandra's *Anekārthasaṅgraha* (36.450).[9]

Conclusion

What has been stated above would show that Āryabhaṭa hailed from the *Aśmaka* country, which comprised the present South Gujarat and North Maharashtra, through which the rivers Godāvarī and Narmadā flowed. He flourished at Pāṭaliputra (modern Patna) in the ancient Magadha country (now Bihar) where he composed his works, the *Āryabhaṭīya* and *Āryabhaṭasiddhānta*. It may be recalled that the reputed University of Nālandā was situated at Pāṭaliputra and had an astronomical observatory (*Kha-gola*) attached to it.[10] Āryabhaṭa who has been described as a *Kulapa* ('head of institution') could well have also been the head of the Nālandā University.

Foot Notes:

1. *Āryabhaṭīya of Āryabhaṭa*, Critical. Edn. & Tr. By K.S. Shukla and K.V. Sharma, Indian National Science Academy, New Delhi, 1976.
2. *Āryabhaṭīya of Āryabhaṭa* with the commentary of Bhāskarācārya and Someśvara, ed. by K,.S. Shukla. Indian National Science Academy, New Delhi, 1976, p.88.
3. *Āryabhaṭīya of Āryabhaṭa*, Critical. Edn. & Tr., p. 96.
4. *Śiṣyadhīvṛddhida* with the commentary of Mallikārjuna Sūri, ed. by Bina Chatterji, Indian National Science Academy, New Delhi 1981.

5. See *Āryabhaṭīya*, Critical. Edn. & Tr., p. 97.

6. For detailed references see: Varāhamihira's *Bṛhatsaṃhitā*, Ed., & Tr. By M. Ramakrishna Bhat, Motilal Banarasidass, Delhi, 1981, pt. I, pp. 177-78; J.F. Fleet, *The Topographical List of Brihat Samhita*, ed. K.K. Das Gupta, *Semushi*, Calcutta, 1973, p. 20; K.D. Bajpai, The Geographical Encyclopaedia of Ancient and Medieval India, Indic Academy, Varanasi, 1967, pp.35-36, *Āryabhaṭīya*, Critical. Edn. by K.S. Shukla and K.V. Sarma, op. cit., Introduction, pp. xxix-xxx.

7. Vide *Āryabhaṭīya*, Critical. Edn. & Tr. Introduction., pp.xxxv-lxii.

8. David Pingree, *Census of Exact Sciences in India*, Philadelphia, *ser.* A. Vol.I, 1970, p.50.

9. See M.M. Patkar, 'Geographical Data in Sanskrit Lexicons,' *Bulletin of the Deccan college Research Institute*, 14.4 (March 1953) 249-305.

10. Vide D.G. Apte, *Universities of Ancient India*, Baroda, p.30. See also, Kripa Shankar Shukla, *Āryabhaṭa: Indian Mathematician and Astronomer* (5th century A.D.) New Delhi, 1976.

Āryabhaṭa and Āryabhaṭan Astronomy: Antecedents, Status and Development*

Vedic Astronomy

Astronomy is apparently the first science which evolved among mankind on account of its presenting itself on its own. The clear night sky, lit by the moon and studded by the stars, and the day, bright with the sun, all in motion in some predicted regularity, obviously fascinated man from the early times. And, not less so the people of the Vedic times who cultivated the discipline as a handmaid for ascertaining the correct times for the conduct of their religious life ridden with sacrifices and allied activities. Naturally enough, their investigations were limited mainly to the observation of the heavenly bodies and the determination of the measures of days, months, seasons and the years besides the determinations of the times of the new and full moons, the equinoxes and the solstices, as also the identification of the 27 constellations and their distribution along the zodiac, being the path of the sun.

In the four Vedas and the allied texts, being the *Brāhmaṇas*, *Upaniṣads* and *Śrauta, Gṛhya* and *Dharmasūtras*, which deal primarily with prayers, rituals and rites, no sequential nor exhaustive account of astronomy, as prevalent during the times, is available. What occurs is causal and as required in the context of the mantras. It is in the *Vedāṅga-jyotiṣa* that a systematic depiction of Vedic astronomical elements, methodologies and practices, besides the purpose of each is to be found. Among these are the methods for time-determination which are most important for the performance of Vedic rituals. Vedic astronomy naturally forms the basis for the further development of Indian astronomy.

The five *Siddāntas*

During the early centuries of the Christian era, Indian astronomy developed as a science for science's sake discipline. Five *siddāntas*

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or Schools of astronomy under the names *Vāsiṣṭha, Paitāmaha, Pauliśa, Romaka and Saura,* arose, inculcating new ideas. Unfortunately, the originals of these *Siddhāntas* are lost but the *Pañcasiddhātikā* of Varāhamihira (6th century) forms an analytical depiction of the salient aspects of each *Siddhānta*. Improving upon the luni-solar astronomy of *Vedāṅga-jyotiṣa*, these *Siddhānta*s deal in detail with planetary astronomy, including the computation of their longitudes, synodic motion, visibility and retrograde motion, problems of space, time and direction (*Tripraśna*), tables of R-sines, declinations of the sun and the moon, gnomonic shadow and derivations with its application, solar and lunar eclipses, phases of the moon and allied matters, thus forming the basis for the scientific astronomy. Of special interest herein is a chapter on astronomical instruments in use and graphical presentation of astronomical depictions and eclipse diagrams. The sphericity of the earth and its motion has also been depicted.

Āryabhaṭa and Scientific Indian Astronomy

Scientific astronomy can be said to have been enunciated in India by Āryabhaṭa I (b. AD 476) who flourished at Kusumapura (Modern Patna) through his two works, the *Āryabhaṭasiddhānta* which is available only in the form of citations by later authors, and as summarised in the *Khaṇḍakhādyaka* of Brahmagupta, and the *Āryabhaṭīya*, a full-fledged work composed in AD 499. Āryabhaṭa was an observer par excellence and, as a result of his investigations, he revised the then current astronomical parameters, introduced new techniques in calculation and established Hindu astronomy on a scientific basis. An anonymous verse describes him as a great teacher who was born in Kusumapurī as the incarnation of the Sun in order to resurrect astronomy when the results arrived at by means of the 'Five *siddhānta*s' began to be erratic.

Cf: सिद्धान्तपञ्चकविधादपि दृग्विरुद्ध-
मौढ्योपरागमुखखेचरचारुक्लृप्तौ ।
सूर्यः स्वयं कुसुमपुर्यभवत् कलौ तु
भूगोलवित् कुलप आर्यभटाभिधानः ।।

The name of Āryabhaṭa is of particular significance to Kerala, for the astronomical tradition of Kerala is wholly based on the *Āryabhaṭīya*.

Āryabhaṭīya

The *Āryabhaṭīya*, couched in 121 aphoristic verses of deep import, is the earliest extant Indian treatise on scientific planetary astronomy. Its first section, called *Gītikā-pāda*, sets out in 13 verses the basic definitions, the main astronomical parameters, the zero-point for the commencement of calculations, the positions of the apogees and the ascending nodes of the planets at the time of the author, the diameters of the earth and the planets, the obliquity of the ecliptic and the inclinations of the planetary orbits to the ecliptic and a table of sine-differences. The second section, *Gaṇita-pāda*, in 33 verses, is concerned with enunciations involving arithmetic, geometry and trigonometry. The third section, *Kālakriyā-pāda*, in 25 verses, gives the units of time, explains the motion of the planets by means of epicycles and enunciates the methods for the determination of the mean and true positions of the planets at any given time. The fourth section, *Gola-pāda*, in 50 verses, deals with the motion of the Sun, Moon and the planets on the celestial sphere and the computation and graphical representation of the solar and lunar eclipses.

Āryabhaṭa's Contribution

Āryabhaṭa's contribution to algebra, trigonometry and astronomy are highly significant. Among them a special mention might be made of the theory of indeterminate equations of the first degree, the imputed value of correct to four decimal places, the computation of the sine-table, the use of the radian measure of 3438 minutes of arc, advanced astronomical parameters, the theory of planetary motion and the correct interpretation and computation of the eclipses.

Earth's Rotation

More significant, perhaps, is the promulgation by Āryabhaṭa of the theory of the rotation of the Earth. Against the current view that the Earth was stationary at the centre of the Universe and that all

heavenly bodies revolved round it, Āryabhaṭa held that the Earth rotated round its axis once in a sidereal day[1] and through an angle of one minute of arc in one *prāṇa* (equal to 1/6 of a *vināḍi*, or 4 sidereal seconds)[2], while the stars were fixed in space[3]. The time for one sidereal rotation of the Earth at the above rate would work out to $23^h\ 56^m{\cdot}4^s.1$, while the corresponding modern value is $23^h\ 56^m\ 4^s.091$. The accuracy of Āryabhaṭa's enunciation is remarkable.

Opposition to Āryabhaṭa

It is highly interesting and, perhaps, intstructive anecdote in the annals of Indian astronomy that the above theory of Āryabhaṭa is known to us from the writings of contemporary and later critics of Āryabhaṭa like Varāhamihira (AD 505), Brahmagupta (A.D. 628), Lalla (8th centry), Śrīpati (A.D. 1039) and Bhāskara II (b. 1114), who severely criticised Āryabhaṭa's theory of the rotation of the earth. For instance in the *Brahmasphuṭasiddānta*, 11.17 appears:

'If the Earth rotates through one minute of arc in one respiration (*prāṇa*), from where does it commence its rotation and where does it go? And, if it rotates (on its axis, at the same place) why do not tall objects (like towers) topple down?'

In the same vein, Lalla asks: 'If the earth rotates (at such a terrific speed) how could birds in flight return to their nests, (for, by the time they returned, the trees on which the nests were would have sped away), missiles thrown vertically upwards would fall towards the west and the clouds would always be moving to the west. If it is argued that the earth is moving at a slow speed, how could it, then, go round the universe in a day'[4].

Decline and Resurgence of the System

Severe criticism, both veiled and open, against the system of Āryabhaṭa, coming as it did from acknowledged authorities, like Brahmagupta, Varāhamihira and Śrīpati, should have confused not only the laymen but also the professionals, and the study of Āryabhaṭan system gradually declined in North India. And, with the wide popularty gained by the great works of Bhāskara II (b. 1114) who followed in the wake of Brahmagupta and Śrīpati, the Āryabhaṭan system was

practically effaced from North India. One does not come across a North Indian manuscript of the *Āryabhaṭīya*, let alone a North Indian commentator, after the time of Bhāskara II.

The Āryabhaṭan system, however, emerged with increased vigour in south of the vindhyas. The superiority of the astronomical parameters and the novel innovations of Āryabhaṭa had given rise to a 'School of Āryabhaṭan astronomy', the followers of which called themselves *Aśmakīya*-s (Advocates of the school of the *Aśmaka* author, viz. Āryabhaṭa') or *Bhaṭaśiṣya*s ('students of Āryabhaṭa). Scholars of South India, comprising of Karnataka, Andhra, Tamilnadu and Kerala, avidly took to the study of the *Āryabhaṭīya* and produced several commentaries[5] and a mass of literature based on the system of Āryabhaṭa[6]. It is specially noteworthy that several systems of almanac computation in the said regions current during the medieval times were based on the Āryabhaṭan manuals[7].

Astronomical Tradition of Kerala

Of the several cultural centres in ancient and medieval India, Kerala stands out as the bastion of the Āryabhaṭan School of astronomy. Situated at the southernmost tip of India, far removed and free from the political troubles and turmoil that affected most of the other parts of the land during medieval times, this part of the country had the opportunity to develop, in an uninterrupted manner, such technical disciplines as medicine, mathematics and architecture. In this wake, Kerala adopted the basic tenets and practices of Āryabhaṭan astronomy and also preserved and developed its tradition for more than thirteen centuries to date-a view that can be postulated for several reasons. Thus, the bulk of the known manuscripts of *Āryabhaṭīya* are from Kerala, written on palm leaf and inscribed in the Malayalam script[8]. Most of the known commentaries on the *Āryabhaṭīya* are authored by astronomers of this part of the country. Thus, of the nearly twenty commentaries on the work known, as many as twelve are by Kerala authors[9]. Practically every astronomical text produced in the land bases itself on the teaching of Āryabhaṭa. The efforts of Kerala mathematicians have been directed also towards the revision, correction and supplementation of Āryabhaṭan astronomy with a view to arriving at

more accurate results. The extensive popularity of Āryabhaṭa in Kerala has tempted some scholars to take him as a native of Kerala, who however, propagated his teachings at Kusumapura (Pāṭaliputra, modern Patna) in Northern India[10]. And, the region of Aśmaka, referred to in later literature as the place from where he hailed, has been taken as a Sanskritisation of the Malayalam place-name Koṭuṅṅallūr in Central Kerala, the untenability whereof has been pointed out elsewhere[11].

Āryabhaṭa's Astronomy in Kerala

Āryabhaṭan astronomy appears to have become popular in Kerala soon after its promulgation by Āryabhaṭa towards AD 500. Kerala texts on the subject attest to its practice and successive revision of parameters, resulting in different systems of computation, at different periods. *Dṛkkaraṇa*; an astronomical manual composed in Malayalam verse in AD 1607-08[12], throws some interesting light in this direction. On the advent of the *Āryabhaṭīya*, the *Dṛkkaraṇa* records in *Pariccheda* 1:

paṇṭuḷḷa gaṇitajñanmār connatoṭṭu paraññīṭām ।
kalyabdam trisahasrattil param cennuḷḷa nāḷilu ॥ 5 ॥
ottuvannīṭumārilla grahaṇādikaḷ onnume ।
karaṇaṅṅaḷum ottīṭā siddāntaṇṇaḷum ottīṭā ॥ 6 ॥
tadā hy āryabhaṭo nāma gaṇakas tv abhavad bhuvi ।
'jñānatuṅge' ti kalyabde jātanāy avanītale ॥ 7 ॥
'girituṅge' ti kalyabde gaṇitam nirmitam param ।
śāstram āryabhaṭīyākhyam tasmin paryayam uktavān[13] ॥ 8 ॥
iva annekkupāyena kūṟaccittum kareṭṭiyum ॥ 12b ॥
kalyādi-dhruvam illāte oppiccān annu paryayam ॥ 13a ॥

'Now, I shall set out in brief what the early astronomers enunciated. Before *Kali* 3000, the eclipses and other observed phenomena did not tally with the astronomical manuals or the *siddāntas* (5-6).

'Then, in the *Kali* year *jñānatuṅga* (3600 = AD 499) an astronomer by name Āryabhaṭa was born in this world (7).

'In the *Kali* year *girituṅga* (3623 = AD 522) was his work *Āryabhaṭīya* composed and therein he stated the revolutions (of the planets) (8).

'He had adjusted these revolutions by reduction and addition in such a way that there was no zero-correction at the beginning of *Kali*' (12b-13a).

The *Parahita* System of Haridatta (AD. 684)

The first major revision, in Kerala, of the astronomical constants enunciated by Āryabhaṭa was effected in AD 683-84 by a set of astronomers who had gathered for the twelve-yearly *Māmāṅkam* (*Mahāmagha*) festival at the religio-educational centre of Tirunāvāy in northern Kerala. The revised system, which came to be known as *Parahitagaṇita* has been enunciated by Haridatta in his *Grahacāranibandhana*[14] and *Mahāmārganibandhana*[15]. The *Dṛkkaraṇa* records this event in the following words:

pinne igganitattinnu nīkkam kaṇṭitu bhūtale ।
'mandasthale'ti kalyabde 'tanute' ti śakābdake ॥ 18 ॥
palarum gaṇitajñanmār kūṭe nokkīṭṭu veccatu ।
kalyabdād 'girituṅgo' nāt śeṣam veccu perukkaṇam[16] ॥ 19 ॥
pērum Parahitam ennu, gaṇitam sūkṣmam ennitu ।
iti niścitya palarum ācariccavanītale ॥ 25 ॥

'In course of time, deviations were observed in (the results arrived at by) this computation (18a). then, in the *Kali* year *Mandasthala* (3785 = AD 684), equivalent to *Śaka tanutā* (606), several astronomers gathered together and devised by observation, (a system), wherein (the correct number of revolutions were to be found) by multiplying the current *Kali* year-minus-'*girituṅga*' (*Kali* 3623, viz. the Āryabhaṭan epoch) by the yearly *Bhaṭābda* or *Śakābda* corrections enunciated (18b-19).

'This system was termed *Parahita* and many followed it, assuring themselves of its accuracy' (25).

The promulgation of *Parahita*, being the revised Āryabhaṭan system, is recorded thus, in another Keralite astronomical work, the *Sadratnamālā* of Śaṅkara Varman (AD 1800-38)[17].

आचार्यार्यभटप्रणीतकरणं प्रायः स्फुटं तत्कलौ
गोत्रोत्तुङ्गमिताब्दके व्यभिचरन्ब्रह्मादिसिद्धान्तके ॥

दृग्वैषम्यवशान्महास्थलमिते कल्यब्दके निश्चितः
संस्कारो विबुधैर्यतः परहितत्वं तेषु वीनेष्वयम् ।।

(*prakaraṇa* 6, verses 1,3)

'Ācārya Āryabhaṭa's astronomical treatise gave well-nigh accurate results in *Kali* year '*gotrottuṅga*' (3623 = AD 522), while the (earlier astronomical) *siddhāntas* ascribed to Brahmā etc. were tending to be inaccurate. When Āryabhaṭan results, too, tended to be inaccurate as exemplified by their not tallying with observations, a correction was decided upon by astronomers (for all planets) other than the Sun, And the revised system was known as *Parahita* because it was acceptable to all'.

Dṛk System of Parameśvara (AD 1431)

The parameters of the *Parahita* system were revised by Parameśvara (AD 1360-1455) through his reputed work *Dṛggaṇita*[18]. The *Dṛkkaraṇa* describes its advent thus:

cirakālam kazhiññappol nīkkam vaḷare vannitu ।
'raṅgaśobhānu' – kalyabde kaścid vipravaras tadā ।। 26 ।।
paścimāmbodhi-tīrattu ninnu nōkkiṭṭu veccatu ।। 27a ।।

'when a long time had elapsed, there occurred substantial deviation (26a).

'Then, (Parameśvara), a noble brāhmin, residing on the coast of the western ocean revised it (i.e. the *Parahita* system) by means of (astronomical) observations, in the *Kali* year *raṅgaśobhānu* (4532 = AD 1431)' (26b-27a).

Revision of Nīlakaṇṭha (AD 1444-1545)

The *Dṛkkaraṇa* specifies the planetary revolutions depicted in the *Tantrasaṅgraha* as pertaining to '12 years later' than those of the previously mentioned revision, i.e. it refers to AD 1443-44, which is the year of birth of the author of the work, Nīlakaṇṭha Somayāji[19].

Cf: dvādaśābdam kazhiññiṭṭu tantrasaṅgraham ennatu ।। 27b ।।

'Twelve years later (were determined the planetary parameters depicted in) the *Tantrasaṅgraha*' (27b)

Revision of *Dṛkkaraṇa*

The *Dṛkkaraṇa* then records its own revision promulgated in AD 1607:

tasmin paryayavum pinne sthūlamāyiṭṭu colliyāl ।
'jasustave 'tī[20] *kalyabdē tuṭarnnār avanītale* ।। 28 ।।
paścimāmbōdhitīrattu ninnu muppatu varṣavum ।
nokkīṭṭu gaṇakanmārum 'janasevā nu' – vatsare ।। 29 ।।
sūkṣmam varutti nirmiccār gaṇitāgamam annavar ।
iniyum kaṇṭukoḷḷēṇam cirakālād varunnatu ।। 30 ।।

'The revolutions given therein (i.e. in *Tantrasaṅgraha*), too, being found to be imperfect, observations were continued by the astronomers on the west coast for thirty years, from the *Kali* year *Jasustava* (4678 = AD 1577) to the *Kali* year *Janasevā* nu (4708 = AD 1607) and, by observation, the astronomical tradition was revised accurately (28-30a).

'Hence forward, too, (the deviations) that would occur should be carefully observed (and revisions effected)' (30b).

This is followed, by the statement of the parameters, in the beginning of the next pariccheda, verses 1-6.

The *Sadratnamālā* also records this revision in the following verse:

प्रत्यक्षतः परहिते गणितेऽपि भेदम्
दृष्ट्वा कलौ जनसभामितवत्सरान्ते ।
राद्धान्तिते तु गणकैर्गणितागमे यद्
दृक्साम्यगामि करणादि तदत्र वक्ष्ये ।। (VI. 43)

'Since the differences between (values derived by) the *Parahita* computation and observation were noted, certain revisions were enunciated in the astronomical tradition by astronomers in *Kali* year *Janasabhā* (4708 = AD 1607). I shall set out here those practices which tend to give results akin to those by observation'. Then are given the new parameters and computational methods.

Comparative Study of the Revisions

Source	Date A. D	Sun	Moon	Moons's Apogee	Moon's Node	Mars	Mercury	Jupiter	Venus	Saturn	No. of days per yuga
Āryabhaṭīyam[21]	499	43,20, 000	5,77,53, 336	4,88,219	2,32,226	22,96, 824	1,79,37, 020	3,64,224	70,22, 388	1,46, 564	1,57,79, 17,500
Parahita of Haridatta[22]	563	•	5,77,53, 314.2	4,88,121.9	2,32, 307.3	22,96, 862.3	1,79,37, 378.0	3,64, 184.0	70,22, 257.8	1,46, 581.0	1,57,79, 17,500
Drggaṇita of Parameśvara[23]	1431	•	5,77,53, 321.009	4,88,123. 229	2,32, 297.832	22,96, 862.959	1,79,37, 072.112	3,64, 172.296	70,22, 270.775	1,46,626. 695	1,57,79, 517.019
Tantra-saṅgraha of Nīlakaṇṭha[24]	1444	•	5,77,53, 320	4,88,122	2,32,300	22,96, 864	1,79,37, 048	3,64,180	70,22, 268	1,46,612	1,57,79, 517,019
Golasāra of Nīlakaṇṭha[25]	c.1486	•	5,77,53, 320	4,88,120	2,32,300	22,96, 864	1,79,37, 040	3,64,180	70,22, 270	1,46,600	1,57,79, 517,019
Siddhānta-darpaṇa of Nīlakaṇṭha[26]	c.1500	•	5,77,53, 332.321	4,88,123. 318	2,32, 226.745	22,96, 862.137	1,79,37, 120.175	3,64, 160.611	70,22, 270.552	1,46, 571.016	1,57,79, 17839.500
Dṛkkaraṇa[27]	1607	•	5,77,53, 320	4,88,122	2,32,298	22,96, 863	1,79,37, 100	3,64,166	70,22, 272	1,46,612	1,57,7917, 839.500

The parameters according to the different revisions mentioned above are set out in the above table, with the textual verses reproduced as footnotes, for verification. This should enable a two-pronged enquiry being made into the subject – first towards identifying the exact methods by which each revision was made and secondly towards determining the relative merit of the succeeding revisions.

Observational Astronomy in Kerala

The tradition of maintaining accuracy in astronomy was of paramount importance. Thus Parameśvara (AD 1380-1460) of Vaṭaśśeri, says towards the beginning of his recently recovered *Dṛggaṇita* (ed. K.V. Sarma, Hoshiarpur, 1963):

दृश्यन्ते विहगा दृष्ट्या भिन्नाः परहितोदिताः
प्रत्यक्षसिद्धाः स्पष्टाः स्युर्ग्रहाः शास्त्रेष्वितीरितम् ।।१,२।।
सत्कर्मोदितकालस्य ग्रहा हि ज्ञानसाधनम् ।
अस्पष्टविहगैः सिद्धः कालः शुद्धो न कर्मणि ।। ३।।
ये तु शास्त्रविदस्तद्वद् गोलयुक्तिविदश्च तैः ।
स्फुटखेचरविज्ञाने यत्नः कार्यो द्विजैरतः ।।४।।

'Planets computed by the *Parahita* system of astronomy are found to be away from their observed positions. In the science (of astronomy), however, it is stressed that the observed positions are the true positions' (1.2)

'Planetary positions alone are the means of ascertaining the times for auspicious rites. And times indicated by incorrect planetary positions are impure for rites (1.3).

'Hence, by those twice-borns who know astronomy and are scholars in spherics, effort should be made towards understanding planetary positions which are true (to observation)' (1.4).

It would be highly instructive to know how Parameśvara, who promulgated the *Dṛggaṇita* system of astronomy in Kerala strove to perfect his system by astronomical observations. He is reputed as a sky-watcher, scanning the sky and recording astronomical phenomena continuously for a number of years. He himself states at one place:

ग्रहेन्द्राः पञ्चपञ्चाशद्वर्षकालं निरीक्षिताः ।
मया, तदा दृशा, भिन्ना दृष्टाः परहितोदिताः ।।

'The planets had been scanned by me for fiftyfive years. Their positions computed according to the *Parahita* system were all different (from those observed).' (Quoted by Nīlakaṇṭha Somayāji in his *Āryabhaṭīya Bhāṣya, Golapāda* p. 157).

Nīlakaṇṭha Somayāji, who imbibed astronomy from Parameśvara, states that Parameśvara composed the *Dṛggaṇita* (AD 1430) on the basis of his astronomical observations for fifty five years

परमेश्वरस्तु रुद्र-परमेश्वरात्मज-नारायण-माधवादिभ्यो गोलविद्भ्यो गणित-गोलयुक्तीरपि बाल्य एव सम्यग् गृहीत्वा तेभ्य एव क्रियमाणप्रयोगस्य दृग्विसंवादं तत्कारणं चावधार्य शास्त्राण्यपिबहून्यालोच्य पञ्चपञ्चाशद्वर्षकालं निरीक्ष्य, ग्रहणग्रहयोगादिषु परीक्ष्य, समदृग्गणितं करणं चकार । (*Ā. Bh. – Bhāṣya* on 4.48, edn. Trivandrum, 1957, p. 154)

'Parameśvara, too, imbibed well, in his younger days the rationale of mathematical and spherical astronomy from astronomers like Rudra, Nārāyaṇa son of (another) Parameśvara, and Mādhava (of Saṅgamagrāma). He identified the differences between observed (planetary) positions and those derived from the computational methods (taught by earlier authorities) and understood the cause of the differences. He thought over the enunciations found in several texts, verified them with the eclipses and planetary conjunctions, and, from a consideration of all matters, composed (his) *Dṛggaṇita*'.

In yet another place, when Nīlakaṇṭha had the occasion to refer to Parameśvara, he says: परमेश्वराचार्येण पुनः ग्रहणग्रहयोगादिकं यन्त्रैः पञ्चपञ्चाशद्वर्षकालं सम्यक् परीक्षितम् (*op. cit.* p. 154)

'Paremeśvara, too examined the eclipses, planetary conjunctions etc. with *astronomical instruments* for fifty five years.' The mention of astronomical instruments in this passage is significant.

In his commentary *Siddhāntadīpikā* on the *Mahābhāskarīya-bhāṣya* of Govindasvāmin (ed. Madras, 1953), Parameśvara has a long disquisition on eclipses, (pp. 321-32), during which he enumerates

a large number of controversial eclipses, solar and lunar, which he had observed. He commences this disquisition with the statement:

'तिथिविश्व'समे शाके प्रारभ्य ग्रहणं मया ।
अनेकमीक्षितं, तेषु भिन्नः कालो दृशा सदा ।। २ ।।
प्रत्यक्षकालस्तेषु प्राग् गणितानीतकालतः ।
अतः कार्योऽत्र संस्कारो यः कश्चिद् गणकोत्तमैः ।। ३ ।। (p.321)

'Commencing from *Śaka* 1315 (AD 1393), a number of eclipses have been observed by me. In all these, the observed times of occultation was different from the computed ones. In them, the *observed times (of the eclipses) were prior to their computed times.* Hence a correction has to be applied in them by astronomers'.

After several arguments and enumerations of eclipses Parameśvara says, towards the close of this disquisition:

उक्तेभ्योऽन्ये चोपरागा मया दृष्टा विवस्वतः ।
इन्दोश्च बहवो दृष्टास्ते तु नोदाहृता इह ।। ८६ ।।
एतानतीतोपरागान् सञ्चिन्त्य परिकल्पिताः ।
विलिख्यन्ते मया भानु-चन्द्र-चन्द्रोच्च-राहवः ।।८७ ।। (p.331)

'Many more solar eclipses as also lunar eclipses than those enumerated above have been noticed by me, but they are not set out here. And, I am indicating below the correct position of the Sun, Moon, Higher Apsis and Node, as determined on the basis of these past eclipses'.

Further down, Parameśvara says:

यदा परहितप्रोक्ता गृह्यन्ते विहगास्तदा ।
कार्यः पूर्वोक्तसंस्कारो यतोऽस्मिन् स्थितिरीदृशी ।। ९२ ।।
कालान्तरे तु संस्कारश्चिन्त्यतां गणकोत्तमैः ।।९३ ।। (p.332)

'When the planets etc. are computed according to the *Parahita* school, the above-indicated corrections have to be done since the present conditions are as stated above. In future also, similar corrections shall have to be thought of by astronomers'.

Another 'astute' astronomer of Kerala was Nīlakaṇṭha Somayāji (born in 1444), a pupil both of Parameśvara and his son Dāmodara, and it was given to him to produce a unique work entitled *Jyotirmīmāṃsā* (Investigations on Astronomy'), solely devoted to discussions on astronomical theories, apparent inconsistencies between computed and observed results, and enunciation of corrections. He makes some instructive statements on observational astronomy as well. This work has been critically edited and published (K.V. Sarma, Hoshiarpur, 1977).

Stressing the experimental nature of astronomical science (*op.cit.* pp. 1-2,5) Nīlakaṇṭha points out that statements in ancinent texts about 'direct instruction by divine beings' do not literally mean that but only the intellectual inspiration experienced by the 'mortal authors' of the texts, who codified the results of their experiments and enunciated the astronomical *Siddhānta*-s. Mark his words: (*op. cit.* p.2)

ननु तपोभिः प्रसन्नो ब्रह्मा आर्यभटाय भगणपरिध्यादिकं ग्रहगणनसाधनभूतं संख्याविशेषमुपदिदेश । तदुपदिष्टं पुनरार्यभटः सर्वं यथोपदिष्टमेव दशभिर्गीतिभिर्निबबन्ध इति केचिन्मन्यन्ते तस्य कुतः परीक्षणम्, ब्रह्मणः सर्वज्ञत्वात्, रागद्वेषाद्यभावाच्च, अवितथत्व-निश्चयात्-इति चेत् - मन्द ! मैवम्, देवताप्रसादो मतिवैमल्यहेतुरेव न च पुनः ब्रह्मा आदित्यो वा स्वयमेवागत्य उपदिशेत् ।

The methodology of astronomical revision adopted by Nīlakaṇṭha by observation and experimentation is unexceptional. He says: (*op, cit.* p. 3):

'गणितोन्नीतस्य चन्द्रादेः देशविशेषान्वयस्य प्रत्यक्षेण संवादः ततो निश्चितान्वयस्य परस्य गणितलिङ्गोपदेशः । ततः तस्याप्तोपदेशावगतान्वयस्य अनुमानं, संवादः, परस्मै चोपदेशः इति संप्रदायाऽविच्छेदात् प्रामाण्यम् ।'

'The correlation of the computed Moon etc. with actual observation at a particular place, the revision of computation on the basis of such correlation, logical inference therefrom being transmitted as tradition, its being again corrected (through observation and again revised) and transmitted further down to others, this is how tradition is

continued without interruption. And, this gives continued authoritativeness to tradition'.

In the same strain, Nīlakaṇṭha continues:

'पञ्चसिद्धान्तास्तावत् क्वचित्काले प्रमाणमेव इत्यवगन्तव्यम् । अपि च यः सिद्धान्तो दर्शनाऽविसंवादी भवति सोऽन्वेषणीयः दर्शनसंवादश्च तदानीन्तनैः परीक्षकैः ग्रहणादौ विज्ञातव्यः ये पुनरन्यथा, प्राक्तनसिद्धान्तस्य भेदे सति, यन्त्रैः परीक्ष्य ग्रहाणां, भगणादिसंख्यां ज्ञात्वा अभिनवसिद्धान्तः प्रणेय इत्यर्थात् तत इहलोके न असहनीयाः परलोके अदण्डनीयाश्चेति ।'

(ज्योतिर्मीमांसा. p.6)

'One has to accept that (each of) the Five *Siddhānta*-s had been authoritative at one time (or another, though they might not be so now). In fact, one has to look for a system which tallies with observation. The said tallying has to be verified by contemporary experimenters at the time of eclipses. When the two differ, i.e. when an earlier system does not agree (with observation), experiments have to be conducted with instruments and the revolution-numbers of the planets calculated afresh. A new system has thus to be expounded. Nobody will be ridiculed for this in this world nor punished in the next'.

Accurately observed eclipses being the most convenient natural phenomena for the verification of astronomical systems and formulation of corrections to current computations. Nīlakaṇṭha advocates this method for the purpose. He says:

'अथ सिद्धान्तदीपिकायाम् उदाहृतानि ग्रहणानि परीक्षमाणेन गण्यानि अन्यानि वा एतिह्यसिद्धानि स्ववंश्यैरुपदिष्टानि गण्यन्ताम् । एतैः प्रत्यक्षावगतैश्च अनागतग्रहणं निर्णीय वक्तव्यम् । जनपदान्तरजान् उपरागान् तद्देशान्तराक्षादिभिः गणयित्वा रवीन्दुतुङ्गपातान् विज्ञाय अतीतमनागतं स्वदेशजं ग्रहणं स्वदेशान्तराक्षाभ्यां विज्ञातैस्तैरेव ग्रहोच्चपातैर्गणयित्वा निर्णेयाः' ।

(ज्योतिर्मीमांसा. pp. 31-32)

'The eclipses illustrated in the *Siddāntadīpikā* (by Parameśvara) might be computed (in all their details) by the experimentor. Even so, might be computed other eclipses handed down by tradition of one's own school. In the light of these and of eclipses actually observed by the experimentor, future eclipses should

be computed and forecast. Or, eclipses occurring at other parts of the country should be computed using the longitude, latitude etc. of that part of the country and, with that as the basis, the True Sun, Moon, Apsis and Node (at the relevant times) ascertained. Then, from the Sun, Moon Apsis and Node as ascertained above, past and future eclipses at one's place shall be computed, using the latitude and longitude of one's own place'.

In his *Jyotirmīmāṃsā*, Nīlakaṇṭha continues the above statement with the enumeration of the several eclipses observed and recorded by Parameśvara, explains the procedures and illustrates the correction with a practical example. (pp.32-36).

The uniqueness of the work *Jyotirmīmāṃsā* and its importance in providing a picture of the practical and observational astronomy during medieval times in Kerala would be clear from the above. The picture would have been clearer had the instruments used by these enterprising astronomers and the manner in which they used them and recorded the observations over long periods of time were available. The instruments, constructed out of perishable material seem to have been lost in the ravages of time and the palm leaves on which rough recordings had been made seem to have been discarded. It is essential that we look for survivals of at least of these to enable us figure out the mental make-up and the actual methodologies of these indefatigable forebears of the astronomical discipline in the land.

Teacher-pupil tradition

Naturally enough, since Astronomy and Astrology are primarily practical disciplines, the Teacher-Pupil tradition was strong in the land. Apart from the practice of authors mentioning the names of their teachers in their works, there are also recorded chronologies of such relationships. Thus, an old palmleaf manuscript of *Sūryasiddhānta-vyākhyā* from Kerala, inscribed in Malayalam, (Ms. No. 9886, Oriental Institute, Baroda) records, towards its end, an astronomical chronology

extending over 400 years and another source extends this chronology by still another 300 years. The relevant passages have been reproduced and elucidated in '*Direct lines of astronomical tradition in Kerala*' (See p. 402). These tables give the chronology: 'Govinda Bhaṭṭatiri of Talakkulattūr (1237-96) → Pupil: Grandfather of Parameśvara*, author of *Dṛgganita* (1360-1430) → Son: Dāmodara (15th century) → Nīlakaṇṭha Somayāji (1443-1555) → Pupil : Jyeṣṭhadeva (1500-1600) →Pupil : Acyuta Piṣāraṭi (1550-1621) →Pupil: Tṛppāṇikkara Poduvāl (16th century) → Pupil: Nāvāyikkulattu Āḷāti (17th century) → Pupil : Pulimukhattu Potti (1686-1785) → Pupil: Rāman Āśān (18th Cent.) → Pupil: Kṛṣṇadāsa (Kṛṣṇan Āśān) (1756-1812).

The above line of astronomers continues further as follows: Kṛṣṇadāsa (1756-1812) → pupil : Dakṣināmūrti Mūssatu of Maṅgalaśśeri, in Āranmula (18th-19th cent.) → pupil : Bālarāman Piḷḷa of Nālekāṭṭil family of Mānnār (19th cent.) → pupil : Prince Rājarāja Varma (Vidvān Karīndran Ceruṇṇi Koyittampurān of Kiḷimānūr) (1812-46).

There must necessarily be many such Teacher-Pupil hierarchies left unrecorded or not fully recorded as the present 700-years long tradition.

Prolific astronomical activity :

A recent survey entitled *Science Texts in Sanskrit in the Manuscripts Repositories of Kerala and Tamilnadu* carried out by the present writer under the auspicies of Indian National Science Academy, New Delhi, has been an eye-opener in the matter of the prolific production of astronomical texts in Kerala. Of the nearly one and a

*For this relationship, see Parameśvara's own words towards the beginning of his commentary on the *Muhūrtaratna* of Govinda :

govindapūjyapādena kṛpāsaṃsiktacetasā /
muhūrtāgamadugdhābdheḥ muhūrtamaṇir uddhṛtaḥ //
tasmiṃs tacchiṣyapautreṇa kiyāṃścid paramādinā /
bhāgo vivriyate svalpam īśvareṇa yathāśrutam //

(Ms. Kerala Univ., Mss. Lib. T.144)

half lakh manuscripts, mostly in palmleaf, contained in about 500 private and public repositories, as many as 12,244 science manuscripts were identified and classified, with full documentation, in the eight science disciplines of: (1) Astronomy and Mathematics, (2) Astrology, (3) Medicine, (4) Veterinary Science, (5) Chemistry, (6) Physics, (7) Botany, and (8) Architecture. While Astrology topped the list in the matter of numbers, Astronomy and Mathematics was the second largest group, and accounted for 2420 manuscripts. The number of independent texts in each discipline was also ascertained, the number of texts in Astronomy and Mathematics being 934. Of these, about 10 per cent or about 100 texts had been made available in print, while the rest, being 90 per cent, still lies unheeded and uncared for in the manuscripts repositories of the land. Indeed, these texts offer to the involved and inquisitive student of Indian astronomy abundant material for investigation towards rewarding results.

Outlook of the Kerala authors

An examination of the above-said texts brings out certain trends in the efforts of their authors. The Kerala astronomer was essentially an innovator and a rationalist. He was not for floating new theories and starting new schools and not even for producing full-fledged texts encompassing all aspects of the discipline, a few texts like the *Tantrasaṅgraha* of Nīlakaṇṭha Somayāji and *Jyotiṣasārasaṅgraha* of Āḷvañceri Tamprākkal, being exceptions. Taking the *Āryabhaṭīya* as the basic text the Kerala astronomers improvised upon its astronomical constants, offered corrections, composed *Karaṇa* texts or practical manuals with contemporary *Khaṇḍadina*-s or cut-off dates to be deducted from the *Kali* days for those dates and give the correct longitudes of the planets for those dates as the *dhruva*-s or zero-corrections to be applied to planetary longitudes for the future, thus making computations easier on account of the smallness of these numbers. They also designed more accurate sine-tables for the planets and the daily motion of the Moon.

Accurate determination of the lunar day or *tithi* and of the asterisms or *nakṣatra* was required for the fixation of every religious

rite and social function and since this depended upon the position of the moon, a number of texts pertained to this topic. Again, since Moon had not only the fastest motion but also changes of velocity even during the same day, texts formulating ingenious and facile methods were evolved towards preparing charts for reading off the position of the Moon on any day and at any time of the day at short intervals several texts have been prepared for drawing such charts. The first work of this type was the *Veṇvāroha* of Mādhava of Saṅgamagrāma. Computation of the times of eclipses, both lunar and solar, forms the subject of a large number of tracts. Computation of the Sun and the Moon based on the gnomomic shadow and related computations have been treated by several astronomers. Long range almanacs comprising of tables from which the astronomical components of any day could be read off formed the subject of certain other texts. Texts explaining the rationale behind astronomical formulae and procedures have been found in several tracts. Spherics and the armillary sphere too have been similarily treated.

Classification of the texts

About 270 select texts of the above type have been listed below in an appendix, as classified under the following heads[28].

Subject	*No. of Texts*
1. *Golaracanā* (construction of the Armillary sphere)	7
2. *Jyāḥ* (R-sines)	18
3. *Vākyāni* (Mnemonic phrases)	17
4. *Khaṇḍa-dhruvāḥ* (Epochs and zero corrections)	20
5. *Karaṇa-granthāḥ*(Astronomical manuals)	28
6. *Saṅkrānti-kriyā* (Computation of Sun's transit)	6
7. *Chandrasphuṭa- kriyā* (Computation of true Moon)	16
8. *Kujādipañcagraha- kriyā* (True longitudes etc. of Mars and other planets)	7

9. *Grahasphuṭa- kriyā* (Computation of true planets) 21
10. *Nakṣatra- kriyā* (Computation of the constellations 5
11. *Krāntyānayana* (computation of declinations) 5
12. *Śṛṅgonnati-kriyā* (Computation of the elevation of the Moon's horns) 4
13. *Valana-kriyā* (computation of deflections) 5
14. *Vikṣepa-kriyā* (Computation of celestial latitude) 4
15. *Candracchāyā-gaṇitam* (Computation of the Moon's shadow) 15
16. *Adhimāsa-granthāḥ* (computation of intercalary months) 6
17. *Grahaṇa-kriyā* (Computation of eclipses) 38
18. *Mauḍhya-gaṇanam* (Computation of retrograde motion) 5
19. *Muhūrta-gaṇanam* (Determination of auspicious times) 7
20. *Lāṭa-vaidhṛta-kriyā* (Computation of Lāṭa and Vaidhṛta) 13
21. *Agaṇita-granthāḥ* (Reading charts) 11
22. *Yuktayaḥ* (Rationales) 9

It is to be hoped that these lists will provide a glimpse of the astronomical treasure lying in the manuscripts repositories in Kerala, unchartered and unrecognized, to be resurrected by enterprising scholars, for the benefit of the astronomical world community. An important point to note is that while several of these works are full-fledged texts with the mention of their authors and author given titles towards their beginnings, ends and/or in colophonic statements, most of them are tracts on unitary topics without naming their authors nor having formal author-given titles, and therefore, recorded as anonymous '(Anon)' under conjectured titles based on their contents. Thus the same title *Candracchāyānayana* ('Computation of the Moon-shadow') for four manuscripts recorded without naming any author would mean four different texts on the same topic by four different authors whose names are not known. It is also worth nothing that while most of these tracts are composed in the Sanskrit language there are several composed in Malayalam, the local language, as well.

Conclusion

It needs to be added that the accounts given and the texts listed through the Survey cannot be considered to be exhaustive for two reasons. First, there still exist many more repositories of manuscripts which have to be identified and their contents scanned. And secondly, even among the manuscripts unearthed there remain several whose contents have yet to be analysed, they having been, for the time being catalogued with such titles as *Jyotiṣa-grantha, Jyotiṣaviṣaya, Gaṇita-yuktayaḥ* and the like. Since the edition, study and rationalization of the major works in Indian astronomy and mathematics are well nigh over it now behoves students both of Indian and modern astronomy to direct their attention to the study of the extraordinarily rich legacy of astronomical writings left behind by the highly enterprising Kerala astronomers of medieval times.

Astronomical tracts by Kerala authors: A classified Bibiliography

I. ***Agaṇita-granthāḥ*** (Reading charts)

1. *Agaṇitam* by Nallūr Subrahmaṇya Śāstri
2. *Agaṇitacāraḥ*, Anonymous
3. *Agaṇitagrahacāraḥ* by Mādhava of Saṅgamagrāma
4. *Agaṇitagrahacāraḥ*, Anonymous
5. *Candrasphuṭāptiḥ* by Mādhava of Saṅgamagrāma
6. *Veṇvārohaḥ* by Mādhava of Saṅgamagrāma
7. *Veṇvārohaḥ*, Anonymous
8. *Veṇvārohānusāri-granthaḥ*, Anonymous
9. *Veṇvārohānusāri-candrasūkṣmasphuṭānayanam*, Anonymous
10. *Veṇvārohāṣṭakam*, Anonymous
11. *Dṛṅveṇvārohakriyā*, Anonymous

II. ***Adhimāsa-granthāḥ*** (Computation of Intercalary Months)

1. *Adhimāsa-kṣayamāsanirṇayaḥ*, Anonymous

2. *Adhimāsanirṇayaḥ,* Anonymous
3. *Adhimāsādinirṇayaḥ*, Anonymous
4. *Adhimāsādiyuktiḥ*, Anonymous
5. *Adhimāsānayanam*, Anonymous
6. *Malamāsanirṇayaḥ,* Anonymous

III. ***Karaṇa-granthāḥ*** (Astronomical Manuals)

1. *Karaṇadarpaṇam* by Bhāradvājadvijaḥ
2. *Karaṇapaddhati* by Putumana Somayāji
3. *Karaṇapaddhatikriyā*, Anonymous
4. *Karaṇaratnam* by Devācārya
5. *Karaṇasāraḥ* by Śaṅkara
6. *Karaṇāmṛtam* by Citrabhānu
7. *Karaṇottamam* by Acyuta Piṣāraṭi
8. *Karaṇāmṛta-vyākhyā* by Acyuta Piṣāraṭi
9. *Kriyāsaṅgrahaḥ*, Anonymous
10. *Grahacāranibandhanam* or *Parahitagaṇitam* by Haridatta
11. *Garhacāranibandhanasaṅgrahaḥ*, anonymous
12. *Dṛkkaraṇam* by Jyeṣṭhadeva
13. *Dṛggaṇitam* by Parameśvara of Vaṭaśreṇi
14. *Pañcabodhaḥ* (i) by Putumana Somayāji
15. *Pañcabodhaḥ* (ii) by Puruṣottama
16. *Pañcabodhaḥ*, (iii) Anonymous
17. *Pañcabodhaḥ* (iv) Anonymous
18. *Pañcabodhaḥ* (v) Anonymous
19. *Pañcabodhaḥ* (vi) Anonymous
20. *Pañcabodhaḥ* (vii) Anonymous
21. *Pañcabodhaḥ* (viii) Anonymous
22. *Pañcabodhaḥ* (ix) Anonymous
23. *Pañcabodhaḥ* (x)·Anonymous
24. *Pañcabodhaḥ* (xi) Anonymous
25. *Pañcabodhaḥ* (xii) Anonymous
26. *Parahitam*, Anonymous

27. Parahitakaraṇam, Anonymous
28. *Parahitagaṇitam*, Anonymous
29. *Vākyakaraṇam* by Parameśvara (au. of *Dṛggaṇita*)

IV. *Kujādipañcagrahakriyā* (True Longitudes etc. of Mars and other Planets)

1. *Kujādigrahacāragaṇitam*, Anonymous
2. *Kujādipañcagrahavākyam*, Anonymous
3. *Kujādipañcagrahavākyaśodhanam*, Anonymous
4. *Kujādiparivartanavākyāni*, Anonymous
5. *Kujādibimbānayanan*, Anonymous
6. *Kujādisphuṭasaṃskāraḥ*, Anonymous
7. *Kujādispaṣṭādhikāraḥ*, Anonymous

V. *Krāntyānayanam* (Computation of Declination)

1. Krāntinirūpaṇam, Anonymous
2. *Krāntipātāryātrayam,* Anonymous
3. *Krāntipātajyā,* Anonymous
4. *Krāntivāsanā,* Anonymous
5. *Krāntyānayana yuktiḥ,* Anonymous

VI. *Khaṇḍadhruvāḥ* (Epoch and Zero corrections)

1. *Khaṇḍajyādiḥ*, Anonymous
2. *Khaṇḍajyāyojanā* , Anonymous
3. *Khaṇḍadinanirṇayaḥ*, Anonymous
4. *Khaṇḍadhruvajyāḥ,* Anonymous
5. *Khaṇḍadhruvāḥ* (i), Anonymous
6. *Khaṇḍadhruvāḥ* (ii), Anonymous
7. *Khaṇḍadhruvāḥ* (iii), Anonymous
8. *Khaṇḍadhruvāḥ* (iv), Anonymous
9. *Khaṇḍadhruvāḥ* (v), Anonymous
10. *Khaṇḍadhruvāḥ* (vi), Anonymous
11. *Khaṇḍadhruvāḥ* (vii), Anonymous
12. *Khaṇḍadhruvāḥ* (viii), Anonymous

13. *Khaṇḍadhruvāḥ* (*kāladarpaṇamārgeṇa*), Anonymous
14. *Khaṇḍadhruvānayanam*, Anonymous
15. *Dhruvānayanam*, Anonymous
16. *Dhruvānayanaprakāraḥ*, Anonymous
17. *Navakhaṇḍāḥ*, Anonymous
18. *Nānākhaṇḍadhruvajyādayaḥ*, Anonymous
19. *Parahitakhaṇḍāḥ*, Anonymous
20. *Sphuṭanirṇayādi-khaṇḍadhruvāḥ*, Anonymous

VII. *Golaracanā* (Construction of the Armillary Sphere)

1. *Goladīpikā* (i) by Parameśvara
2. *Goladīpikā* (ii) by Parameśvara
3. *Goladīpikā* (iii) by Parameśvara
4. *Golasāra* by Nīlakaṇṭha Somayāji
5. *Golakatattvam*, Anonymous
6. *Golatattvanirṇaya*, Anonymous
7. *Golaracanā*, Anonymous

VIII. *Grahaṇakriyā* (Computation of Eclipses)

1. *Uparāgakriyākramaḥ* (i), by Acyuta Piṣāraṭi
2. *Uparāgakriyākramaḥ* (ii), by Nārāyaṇa
3. *Uparāgakriyākramaḥ* (iii), Anonymous
4. *Uparāgaviṃśatiḥ* by Acyuta Piṣāraṭi
5. *Uparāgāṣṭakam*, Anonymous
6. *Grahaṇakriyākramaḥ*, Anonymous
7. *Grahaṇakhaṇḍaḥ*, Anonymous
8. *Grahaṇagaṇanam* (i), Anonymous
9. *Grahaṇagaṇanam* (ii), Anonymous
10. *Grahaṇagaṇitam* by Parakroḍapuradvija
11. *Grahaṇagaṇitam* by Putumana Somayāji
12. *Grahaṇagaṇitam* (i), Anonymous
13. *Grahaṇagaṇitam* (ii), Anonymous
14. *Grahaṇagaṇitam* (iii), Anonymous
15. *Grahaṇagaṇitam* (iv), Anonymous

16. *Grahaṇagaṇitam* (v), Anonymous
17. *Grahaṇagaṇitam* (vi), Anonymous
18. *Grahaṇagaṇitam* (vii), Anonymous
19. *Grahaṇagaṇitam* (viii), Anonymous
20. *Grahaṇagaṇitam* (ix), Anonymous
21. *Grahaṇagaṇitam* (x), Anonymous
22. *Grahaṇadarpaṇam*, Anonymous
23. *Grahaṇadaśakam*, Anonymous
24. *Grahaṇanirṇaya* by Nīlakaṇṭha Somayāji
25. *Grahaṇanirṇaya*, Anonymous
26. *Grahaṇanyāyadīpikā* by Parameśvara
27. *Grahaṇamaṇḍana* by Parameśvara
28. *Grahaṇamadhyavāsanā*, Anonymous
29. *Grahaṇādigaṇitam*, Anonymous
30. *Grahaṇasphuṭagaṇitam*, Anonymous
31. *Grahaṇāṣṭakam* by Parameśvara
32. *Sūkṣmagrahaṇagaṇitam*, Anonymous
33. *Sūryagrahaṇavāsanā*, Anonymous
34. *Sūryagrahaṇavidhi*, Anonymous

IX. *Grahasphuṭakriyā* (Computation of True planets) (See also IV. Kujādipañcagrahakriyā)

1. *Grahagaṇitam* (i), Anonymous
2. *Grahagaṇitam* (ii), Anonymous
3. *Grahagaṇitam* (iii), Anonymous
4. *Grahagaṇitam* (iv), Anonymous
5. *Grahagaṇitam* (v), Anonymous
6. *Grahagaṇitam* (vi), Anonymous
7. *Grahagaṇitam* (vii), Anonymous
8. *Grahagaṇitam* (viii), Anonymous
9. *Grahagaṇitam* (ix), Anonymous
10. *Grahasphuṭakarmavāsanā* (i), Anonymous
11. *Grahasphuṭakarmavāsanā* (ii), Anonymous
12. *Grahasphuṭakriyā*, Anonymous
13. *Grahasphuṭavākyam* (i), Anonymous

14. *Grahasphuṭavākyam* (ii), Anonymous
15. *Grahasphuṭavākyam* (iii), Anonymous
16. *Grahasphuṭavākyam* (iv), Anonymous
17. *Grahasphuṭānayanam*, Anonymous
18. *Grahasphuṭānayane vikṣepavāsanā*, Anonymous
19. *Dṛksphuṭānayanam*, Anonymous
20. *Navagrahasphuṭāḥ*, anonymous
21. *Navagrahasphuṭānayanam*, anonymous

X. ***Candracchāyāgaṇitam*** (computation of the Mcon's shadow)

1. *Chandracchāyāgaṇitam* by Parameśvara
2. *Chandracchāyāgaṇitam* by Nīlakaṇṭha Somayāji
3. *Chandracchāyāgaṇitam* by Putumana Somayāji
4. *Chandracchāyāgaṇitam,* Anonymous
5. *Chandracchāyāgaṇitadaśakam* by Putumana Somayāji
6. *Chandracchāyānayanayuktiḥ*, Anonymous
7. *Chandracchāyānayanopāyaḥ*, Anonymous
8. *Chandracchāyāgaṇana vāsanā*(i), Anonymous
9. *Chandracchāyāgaṇana vāsanā* (ii), Anonymous
10. *Chāyāgaṇanāṣṭakam*, Anonymous
11. *Chāyāgaṇitam*, Anonymous
12. *Chāyālakṣaṇam*, Anonymous
13. *Chāyāviṣayasūtrāṇi*, Anonymous
14. *Chāyāṣṭakam* by Acyuta Piṣāraṭi
15. *Madhyacchāyānayanayuktiḥ*, Anonymous

XI. *Chandrasphuṭakriyā* (Computation of True Moon)

1. *Candrakriyā*, Anonymous
2. *Candragaṇitam*, Anonymous
3. *Chandravākyadhruvānayanam*, Anonymous
4. *Candravākyavāsanā*, Anonymous
5. *Candravākyāni* by Vararuci (*gīr naḥ śreyetyādi*)
6. *Candravākyāni* (*śīlam rājñaḥ ṣriyetyādi*)
7. *Candrasūkṣmasphuṭānayanavāsanā*, Anonymous
8. *Candrasphuṭagaṇitam*, Anonymous

9. *Candrasphuṭavākyaśeṣaḥ*, Anonymous
10. *Candrasphuṭādyānayanam*, Anonymous
11. *Candrasphuṭānayanam*, Anonymous
12. *Śrāddhacandragaṇanam*, Anonymous
13. *Śrāddhacandragaṇanakriyā*, Anonymous
14. *Śrāddhacandragaṇanakriyāsaṅgrahaḥ*, Anonymous
15. *Śrāddhacandrakhaṇḍaḥ*, Anonymous
16. *Śrāddhacandrādigaṇitam*, Anonymous

XII. *Jyāḥ* (R-sines)

1. *Ahargaṇajyāḥ*, Anonymous
2. *Aśvatthagrāmajyāḥ*, Anonymous
3. *Krāntiphalajyāḥ*, Anonymnous
4. *Carajyāḥ*, Anonymous
5. *Jīvānayanam*, Anonymous
6. *Jyāgaṇanayuktiḥ*, Anonymous
7. *Jyāḥ*, Anonymous
8. *Jyākriyā*, Anonymous
9. *Jyāgaṇitam*, Anonymous
10. *Jyānirṇayaḥ*, Anonymous
11. *Jyāvākyam*, Anonymous
12. *Dṛggatijyāḥ*, Anonymous
13. *Parahitajyāḥ*, Anonymous
14. *Parahitādijyāḥ*, Anonymous
15. *Bhujāphalavāsanā*, Anonymous
16. *Mahājīvaḥ su-sūkṣmāḥ*, Anonymous
17. *Mahājyānayanaprakāraḥ*, Anonymous
18. *Mahājyānayanādiḥ*, Anonymous

XIII. *Nakṣatrakriyā* (Computation of the Constellations)

1. *Nakṣatragaṇādinirṇayaḥ*, Anonymous
2. *Nakṣatradīpikā*, Anonymous
3. *Nakṣatranighaṇṭu*, Anonymous
4. *Nakṣatralakṣaṇam*, Anonymous
5. *Nakṣatravākyāni*, Anonymous

XIV. ***Muhūrtagaṇanam*** **(Determination of Auspicious times)**

1. *Aṣṭamījayantīnirṇayaḥ*, Anonymous
2. *Kṛṣṇāṣṭamīnirṇayaḥ*, Anonymous
3. *Janmāṣṭamījayantīsphuṭanirṇayaḥ* by Puradahanapura Dvija
4. *Mahānavamīnirṇayaḥ*, Anonymous
5. *Śrījayantīnirṇayaḥ*, Anonymous
6. *Ṣoḍaṣakriyāphalasaṅgrahaḥ*, Anonymous
7. *Saṅkramakālanirṇayaḥ*

XV. ***Mauḍhyagaṇanam*** **(Computation of Retrograde Motion)**

1. *Mauḍhyagaṇanam*, Anonymous
2. *Mauḍhyagaṇanakriyā* , Anonymous
3. *Mauḍhyagaṇanayuktiḥ*, Anonymous
4. *Vakravicāraḥ*, Anonymous
5. *Vakrāṇi*, Anonymous

XVI. ***Yuktayaḥ*** **(Rationales)**

1. *Gaṇitayuktayaḥ*, Anonymous
2. *Gaṇitayuktibhāṣā*, Jyeṣṭhadeva
3. *Jyotirmīmāṃsā* by Nīlakaṇṭha Somayāji
4. *Natilambanayor vāsanā*, Anonymous
5. *Natilambanavikṣepavāsanā*, Anonymous
6. *Nyāyaratnam* (i) by Putumana Somayāji
7. *Nyāyaratnam* (ii) by Putumna Somayāji
8. *Mandaspuṭasaṃskārayuktiḥ*, Anonymous
9. *Rāśigolasphuṭānayanam* by Mādhava of Saṅgamagrāma

XVII. ***Lāṭa-vaidhṛta-kriyā*** **(Computation of *Lāṭa* and *Vaidhṛta*)**

1. *Lāṭavaidhṛtagaṇitam* (i), Anonymous
2. *Lāṭavaidhṛtagaṇitam* (ii), Anonymous
3. *Lāṭavaidhṛtādigaṇitam*, Anonymous
4. *Lāṭādipañcakam*, Anonymous
5. *Lāṭāṣṭakam*, Anonymous

6. *Vyatīpātakhaṇḍaḥ*, Anonymous
7. *Vyatīpātagaṇitam*, Anonymous
8. *Vyatīpātacandrānayanam*, Anonymous
9. *Vyatīpātādigaṇitam*, Anonymous
10. *Vyatipātādibodhaḥ*, Anonymous
11. *Vyatīpātāṣṭakam*, Anonymous
12. *Vyatīpātenduganitam*, Anonymous
13. *Vyatīpātendvānayanam*, Anonymous

XVIII. *Valana-kriyā* (Computation of Deflection)

1. *Valanayuktiḥ*, Anonymous
2. *Valanaviṣayaḥ*, Anonymous
3. *Valanaviṣayavāsanā*, Anonymous
4. *Valanānayanavāsanā*, Anonymous
5. *Valanaśṛṅgonnatyorvāsanā*, Anonymous

XIX. *Vākyāni* (Mnemonical Phrases)

1. *Ahargaṇavākyāni*, Anonymous
2. *Aharmānavākyāni*, Anonymous
3. *Kalidinavākyāni*, Anonymous
4. *Kujādivākyāni*, Anonymous
5. *Grahavākyāni*, Anonymous
6. *Grahasphuṭavākyāni*, Anonymous
7. *Grahasphuṭanirṇayavākyāni*, Anonymous
8. *Candrasphuṭavākyaśeṣa*, Anonymous
9. *Candrasphuṭavākyāni*, Anonymous
10. *Dvipadacāravākyāni*, Anonymous
11. *Navagrahasphuṭavākyāni*, Anonymous
12. *Māsavākyāni*, Anonymous
13. *Ravipadacāravākyāni*, Anonymous
14. *Varṣavākyāni*, Anonymous
15. *Vākyaśeṣaḥ*, Anonymous

16. *Saṅkrāntivākyāni*, Anonymous
17. *Samudravākyāni*, Anonymous

XX. ***Vikṣepakriyā*** **(Computation of Celestial Latitude)**

1. *Vikṣepamahāvākyam*, Anonymous
2. *Vikṣepacalanavāsanā*, Anonymous
3. *Vikṣepānayanavāsanā*, Anonymous
4. *Vidhorvikṣepacalanam*, Anonymous

XXI. ***Śṛṅgonnatikriyā*** **(Computation of the Elevation of the Moon's Horns)**

1. *Candraśṛṅgonnatibhūta-koṭikarṇānayana-vāsanā*, Anonymous
2. *Candraṣṛṅgonnatisphuṭānayanam (caturviṃśati-vākyaiḥ)*, Anonymous
3. *Śṛṅgonnatigaṇanam*, Anonymous
4. *Śṛṅgonnatiyuktiḥ*, Anonymous

XXII. ***Saṅkrāntikriyā*** **(Computation of the Sun's Transits)**

1. *Saṅkramaṇānayanam*, Anonymous
2. *Saṅkrāntidhruvādiḥ*, Anonymous
3. *Saṅkrāntinirṇayaḥ*, Anonymous
4. *Saṅkrāntivākya*, Anonymous
5. *Saṅkrāntivāsanā*, Anonymous
6. *Saṅkrāntyādigaṇitam*, Anonymous

Notes and References:

1. *Cf.*, क्षावर्ताश्चापि नक्षत्राः 'The rotations of the Earth are sidereal days', *Āryabhaṭīya, Kālakriyā*, 5.

2. *Cf.*, प्राणेनैतिकलां भूः *Āryabhaṭīya*, *Gītikā*, 6. For other specific reference, by later authors to Āryabhaṭa's theory of the rotation of the Earth. *Cf.*: (1) Pṛthūdakasvāmī (A.D. 860), Com. On the *Brahmasphuṭasiddhānta* (Gola, 30); *Ācārya Āryabhaṭenāpi bhūbhramaṇam abhyupagatam, Lokabhayād Bhāskarādibhir*

(Bhāskara 1 of AD 629) *anyathā matvā āryā vyākhyātā*; elsewhere he says: *bhapañjaro sthiraḥ; bhūr eva āvṛtyāvṛtya pratidaivasikau udayāstamayau sampādayati nakṣatragrahāṇām.*' (see Colebrooke's Miscellaneous Essays, Vol. II, p.344). (2) Udayadivākara (AD 1073), Com. On Bhāskara I's *Laghubhāskarīya* (i. 32-33): *bhūbhramaṇam apy ācāryeṇa abhyupagatam, nakṣatrāṇām sthiratā ca*; (3) Makkibhaṭṭa (AD 1377) Com. On Śrīpati's *Siddhāntaśekhara* (i-39): *bhūmiḥ prāṇmukhī bhramati.*

3. *Cf. Āryabhaṭīya, Gola*, 9-10:

अनुलोमगतिर्नौस्थःपश्यत्यचलं विलोमगं यद्वत्
अचलानि भानि तद्वत् समपश्चिमगानि लङ्कायाम् ।
उदयास्तमयनिमित्तं नित्यं प्रवहेण वायुना क्षिप्तः
लङ्कासमपश्चिमगो भपञ्जरः सग्रहो भ्रमति ।।

Just as man in a boat moving forward sees the stationary object (on either side of the river) as moving backward, just so are the 'stationary stars' (*acalāni bhāni*) seen (by people at Laṅkā (the hypothetical city at the equator), as moving exactly towards the west.

'(It also appears as if) the entire structure of the asterisms, together with the planets were moving exactly towards the west of Laṅkā, being constantly driven by the provector wind, to cause their rising and setting.'

4. यदि च भ्रमति क्षमा तदा स्वकुलायं कथमाप्नुयुः खगाः
इषवोऽभिनभः समुज्झिता निपतन्तः स्युरपां पतेर्दिशि ।
पूर्वाभिमुखे भ्रमे भुवो वरुणाशाभिमुखो व्रजेद् घनः
अथ मन्दगमात् तदा भवेत् कथमेकेन दिवा परिभ्रमः ।।

Śiṣyadhīvṛddhida, Golādhyāya, 7, *Mithyājñānādhyāya*, 42-43

For similar criticism, see Varāhamihira's *Pañca-siddhāntikā* (13. 6-7), Śrīpati's *Siddānta-śekhara* (*Gola*., 15-17) and Bhāskara II's *Siddhānta-śiromaṇi*, (*Madhyamādhikāra, Kālamānādhyāya*, 13-14). It is a sad commentary that, in the face of these apparently insurmountable criticisms, the followers of Āryabhaṭa abandoned the theory, effected two minor alterations in the text of the

Āryabhaṭīya towards making it unoffending; viz., the word *bham* ('sidereal sphere') for *bhūḥ* ('earth') in the passage *prāṇenaiti kalām bhūḥ*, (*Gītikā*, 6), and *bhāvartāś cāpi* ('revolutions of the asterisms') for *kvāvartāś cāpi* ('rotations of the earth') in *Kālakriyā*, 5.

5. For commentaries on the *Āryabhaṭīya* by astronomers of Andhra, Karnataka, Maharashtra, Tamilnadu and Kerala, see *Āryabhaṭīya*, Cr. Ed. with Introduction, English Translation, Notes and Comments, by K.S. Shukla and K.V. Sarma, (Indian National Science Academy, New Delhi, 1976), Introduction, pp. xxxv-lvii.

6. For a selection of these works, see *ibid.*, pp. lvii-lxii. For the works composed exclusively by Kerala astronomers, see K.V. Sarma, *A Bibiliography of Kerala and Kerala-based Literature on Hindu Astronomy*, (Hoshiarpur, 1972).

7. For *Vākyakaraṇa* a 14th century manual used in the Tamil-speaking region of India, see the critical edition thereof, with Commentary, Analysis, Notes and Tables, by T.S.K. Sastri and K.V. Sarma, (K.S. Research Institute, Madras, 1962).

8. Nearly 120 mss, of *Āryabhaṭīya* have been recorded in the *New Catalogous Catalogorum of Sanskrit and allied works and authors*, Vol.II, (Madras University, 1966), p. 171. Most of these are of Kerala origin.

9. For details see, K.V. Sarma, *A Bibliography of Kerala and Kerala-based Astronomy and Astrology*, (Hoshiarpur, 1972), pp. 10-11.

10. See, for example, K. Damodaran Nambiar, '*Āryabhaṭan*', *Mātṛubhūmi*, (Malayalam Weekly, Kozhikode), Oct. 18, 1970, pp. 15-16, 42.

11. The equation suggested is: *Koṭum-kal* (hard black-stone=*aṣma* + *ūr* (place). But the real equation is with *Koṭum-kol-ūr* ' the city of stern rule', the name used for the place in the Tamil work Cilappatikāram (4th century) and old Malayalam works.

12. This work, divided into ten sections called *Paricchedas*, appears to have been written by Jyeṣṭhadeva, author of the astronomical

treatise *Yuktibhāṣā*. The date of the composition of *Dṛkkaraṇa* is given in its concluding line thus:

Kolambe 'barhisūnau' vihagagatiyatum nīkki ittham camappū /

'Compute (as instructed) and subtract the planetary positions for Kollam year *barhisūnu* (783) (=AD 1607-8).'

13. Here are given the parameters of the *Āryabhaṭīya*

14. Cr. Ed. By K.V. Sarma with Introduction, K.S. Research Inst., Madras, 1954. See also K.V. Sarma, '*Parahita-gaṇitattinte mūlagrantham*', *Mātṛbhūmi*, (Malayalam Weekly, Kozhikode), Oct.10.1954.

15. This is apparaently the full-fledged theoretical treatise of the *Parahita* system, while the *Grahacāranibandhana* is only its work manual. Manuscripts of the work are yet to come to light, but the work is known through a reference in *Grahacāranibandhana*, 2.44.

16. Here is given the well-known *Bhaṭābda* or *Śakābda* correction.

17. Edited (incompletely) in the Malayalam monthly *Kavanodayam*, (Kozhikode, Vol. 16, 1898). For Mss., see Nos. 8322-B, C. 2136 of the Kerala Uni. Mss. Library, Cr. Edn. K.V. Sarma, Indian National Science Academy, New Delhi, 2001.

18. Cr. Ed, by K.V. Sarma, V.V.R. Institute, Hoshiarpur, 1963. The date of its composition is given towards the end of the work in the verse:

evam dṛggaṇitam śāke trīṣuviśva-mite kṛtam ।
paramādīśvareṇaitat prāyo bhavati dṛksamam ।। II.*46* ।।

The *Dṛggaṇita* has, thus been composed in śaka 1353 (=AD 1431) by Parameśvara (lit., Īśvara' prefixed by the word '*Parama*'). (The results obtained hereby will) tend to be the same as those by observation'.

On the system and the work, see the text and the Introduction to the above mentioned edition, See also, K.V. Sarma,

'*Parameśvarācāryaruṭe Dṛgganitam*', *Mātṛbhūmi*, (Malayalam Weekly, Kozhikode), Aug. 28, 1960, pp. 19-21.

19. On the date of Nīlakaṇṭha, see K.V. Sarma, Cr. Edn. of *Siddhāntadarpaṇa* of Nīlakaṇṭha Somayāji, (Hoshiarpur, 1976), Introduction, pp. xxv-xxvi.

20. The manuscript reads *vasusmareti,* which is, obviously, corrupt. The emendation made fits in with the context.

21. Āryabhaṭa's parameters:

    युगरविभगणाः ख्युघृ, शशिचयगियिङुशुछ्लृ, कु ङिशिबुण्लृष्खृ प्राक् ।
    शनि ढुङ्विघ्व, गुरु ख्रिच्युभ कुज भद्लिझ्नुखृ भृगुबुधसौराः ।।
    चन्द्रोच्च ज़ुंष्खिध,बुधसुगुशिथृन, भृगु जषबिखुछृ शेषार्काः ।
    बुफिनच पातविलोमा बुधाह्न्य अजार्कोदयाच्च लङ्का याम् ।।

    (*Āryabhaṭīya, Gītikā*,3-4)

    नानाज्ञानप्रगल्भस्, तिलबलमसुसूक्ष्मम्, धयेद् राजदम्भो,
    भद्रो दन्तो धरेन्द्रो, निरनुसृगधिसौख्यम्, वरिष्ठोऽभिषङ्गः ।
    दोर्दण्डाग्रेद्रिनाथो, विषमितविपिनं, चन्द्ररेखाम्बुखिन्ने-
    त्यर्कादेः पर्ययाः स्युः क्षितिदिनं अनृशंसः कळार्थी स मर्त्यः ।।

    (In *Kaṭapayādi* notation, *Karaṇapaddhati* of Putumana Somayāji, 1.3)

22. *Bhaṭābda* corrected parameters: The *Parahita*-manual contains only the correction but not the corrected parameters. These calculated fingures are from T.S.K. Sastri and K.V. Sarma, *Vākyakaraṇam,* (Madras, 1962), Introduction, p.xii.

23. *Dṛgganita* parameters (for the *Kalpa*)

    अनूननूलाननरागभिन्नं, धनं नृपेन्द्राङ्गगुणं सुसूक्ष्मम् ।
    धर्माधिरन्तोदितधीररलं, प्रियापरिच्छिन्नसुगन्धसेव्यः ।।
    चोलेन्द्ररासा कविताङ्गनानां, मांसार्थिनां सूत्रखरो नृसंज्ञः ।
    शुद्धान्तचित्रोचितभाग्यनूलो धात्रीफलं प्राश्यदहेर्वनानि ।।
    रोगादसाधुः खरगीरनूनं, सूर्यादिकानां भगणादिकल्पे ।
    क्रमेण सूर्येन्दुकुजेन्दुजेड्यसितासितेन्दूच्चविधुन्तुदानाम् ।।
    धन्या नु सा कामसुकेलिसार्था मान्या नु कल्पे धरणीदिनानि ।

From *Pañcabodham bhāṣā*, ed. by Kanippayyoor Śaṅkaran Nampūttirippāḍ, 2nd edn. Kunnamkulam, M.E. 1107, App., pp. 252-53).

24. *Tantrasaṅgraha* parameters:

दिव्याब्दानां सहस्राणि द्वादशैकं चतुर्युगम्
सूर्यस्य पर्ययाः तस्मादयुतघ्नरदार्णवाः ।। 15 ।।
खाश्विदेवेषुसप्ताद्रिशराश्चेन्दोः कुजस्य तु ।
वेदाङ्गाहिरसाङ्काश्विकरा ज्ञास्य स्वपर्ययाः ।। 16 ।।
नागवेदनभः सप्तरामाङ्कस्वरभूमयः ।
व्योमाष्टरूपवेदाङ्गपावकाश्चबृहस्पतेः ।। 17 ।।
अष्टाङ्गदस्रनेत्राश्विखाद्रयो भृगुपर्ययाः ।
भास्कराङ्गरसेन्द्राश्च शनेः शश्युच्चपातयोः ।। 18 ।।
नेत्रार्काष्टाहिवेदाश्च, खखरामरदाश्विनः ।
खखाक्षात्यष्टिगोसप्तस्वरेषुशशिनो युगे ।। 19 ।।
सावना दिवसाश्चार्क्ष-मार्ताण्डभगणाधिकाः । 20 a ।।

25. *Golasāra* parameters: (Ch. !. Verse 2-4)

विष्णुपदार्थात्यष्ट्यङ्काद्रिस्वरशरभुवो दिनानि भुवः ।
युगदशमांशभवान्यथ सूर्यादीन्दूच्चपातभगणाश्च ।। 2 ।।
खत्रयदन्ताम्बुधयो, यमाग्निपुष्करशरर्षिशैलशराः ।
षडहिषड्काकृतयो, वेदखमुनिपुष्कराङ्कशैलभुवः ।। 3 ।।
धृत्यब्धिरसहुतासाः शैलाकृत्यश्विविष्णुपदमुनयः
वियदङ्गतर्कमनवो यमचन्द्रगजा हि वारिधयः ।। 4 ।।
गगनानि दन्तयमलानि येते युक्त्या समुद्दिष्टाः । 5a ।।

26. *Siddhāntadarpaṇa* parameters:

कोटिघ्नरदवेदाः प्राक् कल्पे सूर्यस्य पर्ययाः
भूदन्तरददेवेषु सप्ताद्यूर्था विधोः क्षितेः ।। 1.2 ।।
खखेषुगोणुणाष्टाश्वाग्न्येश्विद्व्यष्टशरेन्दवः
सप्ताग्न्येकाश्विषण्णागरसाङ्काकृतयो सृजः ।। 3 ।।
स्ववृत्तेर्थाश्वभूखार्काद्र्यग्र्यङ्कात्यष्टयो विदुः
गुरोरीशाङ्गखाङ्कैकवेदाङ्गशिखिनः, कवेः ।। 4 ।।

'द्वीष्वर्थाभ्रभनेत्राक्षिखागा' लंकोदयाच्छनेः
'नृपाशाश्वेषु तर्केन्द्रा', भुवोऽन्ये वारपा ग्रहाः ।। 5 ।।

27. *Dṛkkaraṇa* parameters:

अर्कादिनां पर्ययङ्ङ्ल् केवलं सूक्ष्ममायव
ज्ञानिनां नम्रगो भानुः पर्ययोऽर्कस्य भाषितम् ।। II.1 ।।
नीरलोलोर्मिसत्सोम चन्द्रस्य भगणान्वयः
कुजस्य पर्ययो ज्ञेयो गीतजास्ताळरन्ध्रनुत् ।। II.2 ।।
ज्ञानाढ्योऽसौबुधस्सेव्यश्चन्द्रजस्य प्रकीर्तितः
वागीशस्य तथा ज्ञेयस्स्तुतिकृद्भूतले ननु ।। II. 3 ।।
कवेर्मण्डलसंख्यास्स्युस्त्रीसुखो रात्रिनाथनुत्
मन्दस्य भगणं पित्रे श्रीपतिस्तद्वपुर्ननु ।। II. 4 ।।
पर्ययश्चन्द्रतुङ्गस्य क्रूरः पादादिभिर न नुत्
दुर्धरोऽत्र गिरीरहेर अर्कादिनाञ्च पर्ययः ।। II. 5 ।।
ननामसकलस्सार्थेशायिनो यन्नु भूदिनम् ।। II. 6a ।।

Sadratnamālā parameters:

ज्ञाननिघ्नफलविन्नराङ्गगुणसत्समं रुरुपदार्जवं
लक्षदार्तृधरराडनेकसुगळोत्सुकः क्षितिपभूतलम् ।
श्रीसखीसुरनसा स्फुटाक्षतघटो दधत्खरगरः क्रमात् ।।
भास्करादिभगणाश्च भूदिनं अनीशसायुधसुसंशयः ।। VI.44 ।।

28. For the documentation of the manuscripts of each work with the indication of the Manuscripts Repository where they are available with the accession numbers of the manuscripts see: K.V. Sarma, *Science Texts in Sanskrit in the Manuscripts Repositories of Kerala and Tamilnadu*, Rastriya Sanskrit Sansthan, New Delhi, 2002, and K.V. Sarma, *A Bibiliography of Kerala and Kerala-based Astronomy and Astrology*, Vishveshvaranand Institute, Hoshiarpur, 1972.

DEVĀCĀRYA*

Devācārya, son of Gojanma and author of the astronomical manual *Karaṇa-ratna* (lit. 'Gem of a manual'), hailed from Kerala in South India. The epoch of *Karaṇaratna,* i. e., the date from which planetary computations have been instructed to be commenced in that work, is the first day of the year 611 in the *Śaka* era, which corresponds to February 26 of 689 A. D. This gives the clue to the time of Devācārya to be the latter half of the seventh century. That he belonged to Kerala is evidenced by his using the *Kaṭapayādi* system of letter numerals, and the *Śakābda-saṃskāra* (which is a correction applied to the mean longitudes of the planets from the *Śaka* year 444 or 521 A. D.), and a unique method of computing the solar eclipse, all of which are peculiar to Kerala, and his work being popular in that part of the land.

Devācārya uses the elements of the Āryabhaṭan school of astronomy as the basis of his work, as he himself states towards the commencement of *Karaṇaratna.* Besides the *Āryabhaṭīya,* he has based himself also on the second work of Āryabhaṭa, being the *Āryabhaṭa-siddhānta*, as abridged in the *Khaṇḍakhādyaka* of Brahmagupta. The influence of the *Sūryasiddhānta* and of Varāhamihira are also apparent in his work. It is also noteworthy that Devācārya has himself innovated several hitherto unknown methodologies and techniques in his work.

In eight chapters, the *Karaṇaratna* encompasses almost all the generally accepted aspects of Hindu astronomical manuals. Chapter I of the work is concerned with the computation of the longitudes of the Sun and Moon, and also the five basic elements of the Hindu calendar (*Pañcāṅga*). Computation and graphical representation of the lunar and solar eclipses form the burden of chapters II and III. Chapter

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IV deals with problems related to the gnomonic shadow, and chapter V with the calculation of the time of moonrise and allied matters. In chapter VI, heliacal rising of the Moon and elevation of Moon's horns are dealt with. The last two chapters are concerned with the derivation of the longitudes of the planets, planetary motion, and planetary conjunctions.

Several peculiarities characterize Devācārya's work. Among these are the computation of the Sun, Moon, Moon's apogee and Moon's ascending node using the 'omitted' lunar days, the *Śakābda* correction, and the application of a third visibility correction for the Moon. However, what is most significant in the work is the recognition of the precession of the equinoxes and the rule that has been given for its determination on any date. Devācārya's measure of the rate of precession is 47 seconds per annum, its modern value being 50 seconds. The importance of Devācārya lies also in his work forming a record of the astronomical practices and the methodologies adopted for the quick derivation of astronomical data, that prevailed in India during the 7th century A. D.

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THE *PAÑCASIDDHĀNTIKĀ* OF VARĀHAMIHIRA: A PUZZLING PROBLEM IN IT'S PRESEN 'LY AVAILABLE TEXT*

Introductory

The *Pañcasiddhāntikā* (*PS*)[1], the astronomical work of the sixth century astronomer Varāhamihira (VM) is, as its name implies, a treatise concerning Five Systems of Indian astronomy. These were current during the early centuries of the Christian era, and are *Paitāmaha-siddhānta, Vāsiṣṭha-siddhānta, Pauliśa-siddhānta, Romaka-siddhānta* and *Saura-siddhānta*. The value of the *PS* is all the more so for the reason that the original text of none of these five systems is available now, presumably on account of their desuetude. This would mean that the *PS* is the only authentic source that gives one an idea of the nature and contents of these five systems. However, it is necessary to stress here that the treatment of these systems found in the *PS* is neither in the form of extracts nor of full summaries, nor in the original words of these systems, as is often supposed. In fact, the *PS* is a 'selective' 'resume' of certain sections of the systems, given in VM's own words. More than this, there are verses in the work where two systems are compared, treated together, one stated to be following another, one being superior to another and one being superior to the others in certain aspects but not so in certain other respects.

The puzzle in *Pañcasiddhāntikā*

Varāhamihira, it is well known, is a prolific writer with a dozen works to his credit. It is also well known that his works are characterised by sequential and logical arrangement of the topics and methodical and systematic presentation of those topics. The popular *Bṛhajjātaka* and *Bṛhatsaṃhitā* bear ample testimony to this aspect of his writings. However, his *Pañcasiddhāntikā*, 'as it is available now', lacks this

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*Adyar Library Bulletin, 59 (1995).

distinctive characteristic of VM. This would be clear from the disposal herein of the several chapters and their contents. The colophons to the several chapters read:

ch.

1. *Karaṇāvatāraḥ:* Introduction to the work which is a manual.
2. *Nakṣatrādicchedaḥ:* planetary computation etc. in *Vasiṣṭha-siddhānta*.
3. *Pauliśa-siddhāntaḥ*: planetary computation etc..
4. *Karaṇādhyāyaḥ*: chapter on *Karaṇa* (i.e. Problems of Space, Time and Direction).
5. *Śaśidarśanam*: Moon's cusps (in *Pauliśasiddhānta*).
6. *Candragrahaṇam*: Lunar eclipse (in *Vāsiṣṭha* and *Pauliśa-siddhānta*s).
7. *Pauliśa-siddhānte Ravigrahaṇam*: *Pauliśa-siddhānta*, Solar eclipse.
8. *Romaka-siddhānte Ravigrahaṇam*: *Romaka-siddhānta*, Solar eclipse.
9. *Saura-siddhānte Ravigrahaṇam: Saura-siddhānta*, Solar eclipse.
10. *Candragrahaṇam*: Lunar eclipse (in *Saura-siddhānta*).
11. *Anuvarṇanam*: (Eclipse diagrams).
12. *Paitāmaha-siddhāntaḥ*: *Paitāmaha-siddhānta* (Some topics).
13. *Trailokyadarśanam*: Situation of the Earth and Cosmology.
14. *Chedyaka-yantrāṇi:* Graphical methods and astronomical Instruments.
15. *Jyotiṣopaniṣad*: Secrets of astronomy.
16. *Saura-siddhānte Madhyagatiḥ*: *Saura-siddhānta,* Mean motion (and Mean planets).
17. *Tārāgraha-sphuṭīkaraṇam:* True planets (in *Saura-siddhānta).*
18. *Pauliśa-siddhānte Tārāgrahaḥ*: (*Vāsiṣṭha*) and *Pauliśa-siddhānta*s, rising and setting of planets.

Incomplete and often incorrect specification of the subjects and the disconnected arrangement of the topics as above do not do much justice to any author, let alone the meticulous Varāhamihira. Thus, while the planetary computations according to the *Vāsiṣṭha-siddhānta* are stated in ch. 2, its Lunar eclipse is described in ch. 6, and rising and setting of planets in ch. 18. of *Pauliśa-siddhānta*, planetary positions are in ch. 3, while phases of the Moon are dealt

with in ch. 5, lunar eclipse in ch. 6, solar eclipse ch. 7, and rising and setting of planets in ch. 18. of the *Saura-siddhānta*, while Mean and True planets are depicted in two later chs. 16 and 17, its Lunar eclipse has been dealt with earlier, in ch. 10, and solar eclipse in ch. 9, and rising and setting of planets in ch. 17. Chapter 12, in just 6 verses, on the *Paitāmaha-siddhānta* mentions just a few general things. In between the above different chapters have been placed, with no apparent logic of sequence, Eclipse diagrams in ch. 11, situation of the earth cosmology in ch. 13, astronomical instruments in ch. 14, and *Jyotiṣopaniṣad* (Secrets of Astronomy) in ch. 15. Obviously, no effort seems to have been made to give the chapters in full and arrange the topics in due sequence. The colophons are often incomplete, non-uniform and not self-explanatory.

The above-noted situation of the text of *PS* 'as available today' is surprising. For an explanation one shall have to go to the 'lone' manuscript of the *PS*, on the basis of which all the other manuscripts are derived directly or indirectly. It is from the said 'lone' manuscript all the editions of the work have been prepared. This 'lone' manuscript is highly defective and exhibits corrupt readings, interchange of words, lacunae, and displacement of long passages, which are found in every one of the manuscripts available. G. Thibaut describes this manuscript as 'imperfect and fragmentary' (*cf.* Preface to his edition, P.V), and D. Pingree, the next editor, says: 'The present edition of the *PS* does not solve all the remaining problems connected with the text. We suspect that much will never be understood unless better manuscripts material becomes available'. (of. his edition, Pt. I p.19.).

This piquant state of affairs gives rise to the doubt as to whether the text which is available in the said 'lone' manuscript represents the 'final' or 'full' form of Varāhamihira's work, at all. Circumstances conduce to the feeling that the 'lone' manuscript is after all, just an 'interim draft' of the work, which had somehow been preserved and has come down to later times, as copied in the 'lone' manuscript. However, the genuineness of this 'Draft' as the basis of the fuller and properly presented text of *PS* cannot be disputed. The reason for this

is that *Pañcasiddhāntikā* has been referred to by Varāhamihira himself as his karaṇa ('astronomical manual') in his *Bṛhatsaṃhitā* (17.1) and most of the verses quoted by later astronomers as from *PS* occur herein. Thus Utpala (Bhaṭṭotpala) quotes as many as 117 verses from *PS* in his commentary on the *Bṛhatsaṃhitā* of Varāhamihira, Pṛthūdakasvāmi, 8 verses in his commentary on *Khaṇḍakhādyaka* of Brahmagupta, Sūryadeva Yajvan, 33 verses in his commentary on the *Āryabhaṭīya*, Parameśvara, one verse in his commentary on *Āryabhaṭīya*. Nīlakaṇṭha Somayāji, 3 verses in his *Jyotirmīmāṃsā,* and six verses in his Bhāṣya on the *Āryabhaṭīya*, and Makkibhaṭṭa, 5 verses in his commentary on Śrīpāti's *Siddhānta*śekhara.[2]

The conclusion that Varāhamihira's *PS* is a bigger text than what has been preserved in the 'lone' manuscript, a point made also by Pingree (vide his edition, p. 21), is borne out from other considerations as well. For one thing, some of the verses quoted by later astronomers as from *PS* are not to be found in the 'Draft' *PS*. e.g. *PS* 4.43 c-d, 44, 45 a-b, and 6. 8a-b, quoted by Utpala and incorporated in the editions of *PS*, with due mention of their source, and two other verses quoted by Nīlakaṇṭha Somayāji in his Bhāṣya on *Āryabhaṭīya*. In his *Bṛhatsaṃhitā,* 17.1, where he refers to his '*Karaṇa*' (i.e. *PS),* Varāhamihira says also that in that work he had dealt also with the conflicts (i.e. transists) of the planets according to the *Sūryasiddhānta*. cf. the verse:

yuddham yathā yadā vā
bhaviṣyad ādiśyate trikālajñaiḥ /
tadvijñānam '*karaṇe*' *mayā*
kṛtam sūryasiddhāntāt // *B.S.* 17.1

In the present 'lone' manuscript however, no such treatment is to be found. Moreover, there are several instances of minor variations in the readings of the verses as found in the 'lone' Ms. from those found in the quotations. Then again, Utpala, who had with him a full-fledged text of the *PS* speaks also of an abridgement thereof by Varāhamihira himself. Thus, introducing his commentary on the *Laghujātaka* of Varāhamihira, Utpala says: Varāhamihiraḥ...

Jyotiśśāstrasaṅgraham kṛtvā, tad eva vistara-granthabhīrūṇām kṛte saṅkṣiptam gaṇita-śāstram kṛtvā, horāśāstram vaktukāmaḥ.. (Varāhamihira, after writing the 'condensation of astronomical works', wrote also an abridged version thereof for the sake of those who are averse to longish works, is now attempting to write on *horāśāstra...*').

The above considerations would tend to show that the text of *PS* contained in the 'lone' manuscript, which alone is available now and which or its derivatives have been used for editing the text, is only a 'draft' of the work which has come down to us and does not represent the 'full and final' text of Varāhamihira's *PS.* It behoves upon scholars to look for manuscripts of the full-fledged *PS* during their forays for manuscripts.

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1. a. The text edited with an original commentary in Sanskrit, by Sudhakar Dwivedi and an English Translation and an Introduction by G. Thibaut. Leipzig Benares, 1889. Rep. Lahore, 1930; Varanasi, 1968.

   b. *The Pañcasiddhāntikā of Varāhamihira*, Ed., Tr. by O. Neugebauer and D. Pingree. Kobenhavn, Munksgaard, 1970, 2pts.

   c. The *Pañcasiddhāntikā* (. *Pañcasiddhāntikā of Varāhamihira* with Translation by T.S. Kuppanna Sastry. Critically edited with Introduction and Appendices by K.V. Sarma, P.P.S.T. Foundation, Madras-20, 1993 (now available in SSES Res. Centre).

2. See *PS*, Edn. K.V. Sarma, Appendix II. Index of *PS* verses quoted by later Astronomers, p. 371.

आचार्यवराहमिहिरः - तस्य वैशिष्ट्यम्*

वेदकालादारभ्य भारते वर्षे सम्यक् सम्पोषितं वर्तते ज्योतिश्शास्त्रमिति सर्वे जानन्त्येव । वैदिकसंहितासु तत्र तत्र यथावसरमुपलक्षितं वर्तते ज्योतिश्शास्त्रम् । तं शास्त्रमन्तरा कालज्ञानं न संभवति, कालज्ञानमन्तरा यज्ञकर्मणां सम्पत्तिर्न भवति । यज्ञमन्तरा मोक्षोपायो न विद्यते इति कृत्वा ज्योतिषं प्रति एतद् उच्यते -

वेदस्य निर्मलं चक्षुर्ज्योतिश्शास्त्रमकल्मषम् ।
विनैतदखिलं श्रौतं स्मार्तं कर्म न सिद्ध्यति ।। इति ।।

वेदाङ्गज्योतिषे लगधाचार्येणाप्युक्तम् -

वेदाः हि यज्ञार्थमभिप्रवृत्ताः कालानुपूर्वाः विहिताश्च यज्ञाः ।
तस्मादिदं कालविधानशास्त्रं यो ज्योतिषं वेद स वेद यज्ञान् ।। इति ।।

षण्णां वेदाङ्गानां मध्ये ज्योतिषस्य अग्रिमं स्थानमधिकृत्य तेनैवोक्तम् -

यथा शिखा मयूराणां नागानां मणयो यथा ।
तद्वत् वेदाङ्गशास्त्राणां ज्योतिषं मूर्धनि स्थितम्।। इति ।।

एतादृशस्य ज्योतिश्शास्त्रस्य प्रमुखवक्तृषु अन्यतम आसीद् अनेकग्रन्थप्रणेता आदित्यदासतनयः सूर्यप्रसादलब्धविभवः अवन्त्यां प्रथितयशाः वराहमिहिराचार्यः । काव्ये कालिदासः, नाट्ये भरतः, वैद्ये चरकः इतिवद् गणित-होरा-संहिताभिर्विभक्तस्य त्रिस्कन्धात्मकस्य ज्योतिश्शास्त्रस्य विशारदो वराहमिहिरः । पूर्वमेव तैः ज्योतिश्शास्त्रस्य विभाजनं कृतं, गणितं, होरा संहिता चेति (बृहत्संहिता १.९)। शास्त्रेऽस्मिन् शतकृत्वो वर्त्तन्ते ज्योतिश्शास्त्रविशारदाः ग्रन्थकाराः। तेषु आर्यभट-ब्रह्मगुप्त-लल्लप्रभृतयः केवलं गणितस्कन्धविशारदाः।

**Kālavijñāna*, 1980 pp. 52-55 Bhāratīya Jyotirvojñāna Anusandhāna Samsthān, Saharanpur, U.P.

अन्ये कल्याणवर्म-दिवाकर-नीलकण्ठदैवज्ञप्रभृतयः केवलं होरास्कन्धविशारदाः। संहितास्कन्धप्रवर्तकास्तु विरलाः गर्ग-पराशर-बल्लालप्रभृतयः। एते सर्वे केवलमेकस्कन्धविशारदाः, द्वित्राः स्कन्धद्वयस्य च परं त्रिष्वपि स्कन्धेषु प्रथितप्रज्ञः आधारितग्रन्थप्रणेताचार्यवर्यो वराहमिहिरः । अस्य कृतिषु पञ्चसिद्धान्तिका नाम पौलिश-रोमक-वासिष्ठ-सौर-पैतामहान् सिद्धान्तान् आधारीकृत्य कृतो गणितग्रन्थः। गणितस्कन्धे अन्योऽपि ग्रन्थः तेन व्यरचीति भट्टोत्पलवाक्येन ज्ञायते, येनोक्तं स्वकृतलघुजातकव्याख्यायाः प्रारम्भे 'वराहमिहिरः . . . . ज्योतिश्शास्त्रसङ्ग्रहं कृत्वा तदेव . . . ग्रन्थभीरूणां कृते संक्षिप्तगणितशास्त्रं कृत्वा' इत्यादि । होरास्कन्धे वराहमिहिरेण बृहज्जातकं, लघुजातकं (सूक्ष्मजातकं), बृहद् विवाहपटलं, स्वल्पविवाहपटलं चेति ग्रन्थचतुष्कं निरमायि । संहितास्कन्धे तु बहवो ग्रन्थाः तेन विनिर्मिताः, यथा - बृहत्संहिता, समाससंहिता (स्वल्पसंहिता), वटकणिका, बृहद्यात्रा (महायात्रा, यक्ष्येश्वमेधीया यात्रा, बृहद्योगयात्रा), योगयात्रा, स्वल्पयात्रा (टिकणिकायात्रा) इत्यादि ।

अन्येऽपि सन्ति वराहकर्तृकत्वेन कथिता कृतयः । यथा - पञ्चपक्षी, दैवज्ञवल्लभा, प्रश्नचूडामणिः, प्रश्नमहोदधिः, प्रश्नचन्द्रिका, अङ्गचूडामणिः, जातकार्णवसङ्ग्रहः, योगार्णवः, ज्योतिषार्णवः, सूतिकाध्यायः, पुष्करिण्यादिपद्धतिः, तटाकपद्धतिः, जातकाभरणं, दशचिन्तामणिश्च । एतेषां कर्तृकत्वं च पुनः विचारणीयं वर्तते । परं एतद् सुनिर्णयं यद् वराहमिहिरः त्रिष्वपि स्कन्धेषु बहुग्रन्थकर्ता आसीद् इति ।

अपरमस्ति वैशिष्ट्यं वराहस्य यद् सः आर्षं ज्योतिश्शास्त्रं आमानुषं चकार । बृहत्संहितायाः प्रारम्भे सः कथयति - ऋषिविरचितमेव शास्त्रं साधु मनुते साधारणो जनः मनुष्यकृतं तु असाध्विति । एतन्न तथ्यम् । मुनिविरचितं मन्त्रं भवतु, परं तदेवार्थं संगृह्य मनुजेन कथ्यते चेत्, तदपि अर्थबोधकत्वे पूर्वस्य तुल्यं भूयाद् इति स समर्थयति । यथा -

मुनिविरचितमिति यत् चिरन्तनं साधु न मनुजग्रथितम् ।
तुल्येऽर्थेऽक्षरभेदाद् अमन्त्रके का विशेषोक्तिः ।। इति

(बृहत्संहिता १.३)

अत्रोदाहरणमपि ददाति वराहः - स पृच्छति - यदि ब्रह्मणा क्षितितनयदिवसवारो न शुभकृत् इति कथ्यते, तस्यैवाशयमावाह्य " कुजदिनमनिष्टं " इति अद्यतनीयो ग्रन्थकर्ता कथयति चेत् उभयोर्वाक्ययोः अर्थापादने न कोऽपि भेद इति । अत्र तद्वाक्यम् -

क्षितितनयदिवसवारो न शुभकृदिति पितामहप्रोक्ते ।
कुजदिनमनिष्टमिति वा विशेषो नृदिव्यकृते ।। इति
(बृहत्संहिता १.४)

अपरं चास्ति वाराहं वैशिष्ट्यम् । न केवलं स आर्षं वाक्यमनूद्य मानुषवाक्येन लोकहितार्थं वितरति, परन्तु भारतीयेतरमपि शास्त्रं श्रेष्ठं प्रतिभाति चेत् तदपि लोकोपकारार्थं स्वीकरोति । अत्र समर्थनं च तेनोक्तं यथा - म्लेच्छापराभिधेया यवनाः ज्योतिषं सम्यगधीतवन्तः । तैः तच्छास्त्रस्य य उत्कर्षः सोऽप्यङ्गीकरणीय, तेऽपि पूजनीयाश्च इति । इदं च तद्वाक्यम्-

म्लेच्छा हि यवनास्तेषु सम्यक् शास्त्रमिदं स्थितम् ।
ऋषिवत् तेऽपि पूज्यन्ते ।। इति (बृहत्संहिता १.२१)

वैदेशिकानां परिज्ञानस्य सम्यग्ग्रहणं, तेषां शास्त्रस्य एवं रूपमभिनन्दनं च सर्वत्र न दृश्यते । वराहमिहिरस्य सुजनतायाः परगुणग्राहितायाश्च प्रतीक इव प्रतिभाति एतद् वचनम् ।

भारतस्य सर्वेषु प्रान्तेषु वराहस्य कृतीनां हस्तलिखित-मातृकाणाम् उपलब्धिरेव तासां कृतीनां सर्वत्र प्रचुरप्रचार आसीद् इत्यत्र निदर्शनम् । वाराहकृतिषु बृहज्जातकस्य अन्यादृशी स्वीकृतिरासीद् इति ज्ञायते । अत्र पश्यैतदेकं निदर्शनम् - उज्जयिनीतः विदूरे स्थिते केरलप्रान्ते केरलभाषायां गीर्वाण्यां च तत्प्रान्तीयैः ज्योतिषिकैः कृताः प्रायः पञ्चविंशतिभिन्नाः व्याख्याः समुपलभ्यन्ते । एतदेव प्रस्तौति ग्रन्थस्यास्य तत्रत्यं प्रचुरप्रचारम् ।

बृहत्संहितायां दैवज्ञलक्षणं प्रतिपादयता मिहिरेण स्वकीयमेव चित्रं प्रदर्शनं इव भाति । यथा - अथातः संवत्सरसूत्रं व्याख्यास्यामः । तत्र संवत्सरोऽभिजातः, प्रियदर्शनो, विनीतवेषः, सत्यवाग्, अनसूयकः, समः, सुसंहितोपचितगात्रसन्धिः,

अविकलः, चारुकरचरण-नखनयन-चिबुक-दशनश्रवण-ललाटभ्रूत्तमाङ्गो, वपुष्मान्, गम्भीरोदात्तघोषः, शुचिर्दक्षः, प्रगल्भो, वाग्मी, प्रतिभानवान्, देशकालविभागवित्, सात्विको, न परिषद्भीरुः, सहाध्यायिभिरभिभवनीयः, कुशलोऽव्यसनी, शान्तिक-पौष्टिकाभिचार-स्नानविद्याभिज्ञो, विबुधार्चन-व्रतोपवासनिरतः, स्वतन्त्राश्चर्योत्पादितप्रभावः, पृष्ठाभिधायी, अन्यत्र दैवात्ययात् ग्रहगणितसंहिता-होराग्रन्थार्थवेत्ता, चतुर्णां च मासानां सौरसावननाक्षत्रचान्द्राणाम् अधिमासकावमसम्भवस्य च करणाभिज्ञः, सौरादीनाञ्च मानानां सदृशासदृशयोग्यायोग्यत्वप्रतिपादनपटुः, सिद्धान्तभेदेऽप्ययननिवृत्तौ प्रत्यक्षसममण्डलरेखासम्प्रयोगाभ्युदितांशकानां छायायन्त्रदृग्गणित-साम्येन प्रतिपादनकुशलः, सूर्यादीनां च ग्रहाणां शीघ्रमन्दग्राम्योत्तर-नीचोच्चगतिकारणाभिज्ञः, ग्रहणादिमोक्षकाल-दिक्-प्रमाण-स्थिति-विमर्द-वलन-वर्णादेशानाम् अनागत-ग्रहसमागम-युद्धानामादेष्टा, प्रत्येकं ग्रहभ्रमण-योजनकक्ष्या-प्रमाणप्रतिविषय-योजनपरिच्छेदकुशलः, भूभगणभ्रमणस्संस्थानाद्याक्ष्या-वलम्बकाहर्व्या-सचरदलकाल-राश्युदय-छाया-नाडीकरण-प्रभृतिषु क्षेत्रकालकरणेष्वभिज्ञः, नानाचोद्यप्रश्न-भेदोपलब्धिजनितवाक्सारनिकष-सन्तायाभिनिवेशैः कनकस्येवाधिकतरम् अमलीकृतस्य शास्त्रस्य वक्ता तन्त्रज्ञो भवति। (बृहत्संहिता २.१ (२-९))

त्रिस्कन्धपारदर्शिनो वराहमिहिरस्य अन्वर्थप्रतिपादक एव व्याख्यान-विशेषः । इति

भारतसंस्कृतेः सभ्यतायाश्च प्रणयवतः कस्य भारतीयस्य मनः एतादृशमाचार्यं प्रति नाकृष्टं भवति परमया भक्त्या अकृत्रिमप्रश्रयेण च ? एतादृशमाचार्यं पुनः पुनरानम्य मद्भक्तिप्रदर्शनाय प्रकृष्टतमः अवसरोऽयम् ।

मिहिरं वराहमिहिरं वन्दे सन्देहवेदिनं जगताम् ।
ज्योतिश्चक्रविभावनहेतुं जगदेकचक्षुरक्षुद्रम् ।।

SCIENCES OF ANCIENT INDIA AND SANSKRIT : AN INTROSPECTION*

It is noticed that the rich vocabulary, copious synonyms, and precision in expression, which characterize the Sanskrit Language, greatly conduce to its adaptability as a language for the expression of the science disciplines. Its phonetic script and precise grammar add to the said adaptability. Added to, these are the methodologies which have been systematically developed in several science disciplines and forming distinct chapters depicting these methodologies. The texts like the *Carakasaṃhitā, Suśrutasaṃhitā, Aṣṭāṅgahṛdaya, Viṣṇudharmottarapurāṇa, and Arthaśāstra* define, explain and illustrate these methodologies, called *Tantrayuktis.* It is interesting that there is a full-fledged work entitled *Tantrayuktayaḥ* by Nīlameghācārya which bear evidence to the importance of methodology in Sanskrit technical literature.

Intorduction

A matter that would strike one as one enters the portals of Indian Science is its meticulous presentation and analytical fervour. Whether it is Astronomy or Astrology, Medicine or Architecture, or any other discipline, the case is the same. Now, Science has to be expressed in a scientific form, in other words, in such a manner that the expressions employed are short, clear cut, precise, fully meaningful, with no over or under statements, not liable to be misconstrued, impressive and easily understood and remembered. Perhaps, the Sanskrit language fulfils all these requirements in an exemplary manner. Its fabulously rich vocabulary, with copious synonyms having differing shades of meanings, is capable of reflecting any idea intended. The wealth of verbs conduces to the same effect. This is further aided by the possibility of nominal and verbal formations and a variety of affixes and suffixes of specific significances. The numerous indeclinables also

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play their part. Last, but not least, the word combinations come in handy to give any shade of meaning to any word, making the Sanskrit language extremely expressive.

Still another important aspect of the Sanskrit language is its phonetic script and pronunciation. Its alphabet numbering 51 letters represents all basic human sounds. Besides, their definitive pronunciation is of single importance, in that any single letter is amenable only to a single pronunciation and only a single specific letter of the alphabet represents each single pronunciation. Thus we have in Sanskrit a language, which is completely phonetic in character, something that practically no language in the world can boast of. This aspect of already existing and established 'speech recognition' which is germane to Sanskrit requires every person from any part of the world to spell Sanskrit and pronounce it only in the prescribed manner, with the result that any writer, reader, speaker and listener of the language employs it in an identical manner. This eliminates the possibility of any confusion in any respect. This makes the expression of science through Sanskrit most explicit and effective. This facilitates also the exact and non-confusable letter and word mnemonics required in the expression of numerals and even large numbers necessitated in the disciplines of Mathematics and Astronomy.

Still another matter, which should not be missed, is that the language used in science texts in Sanskrit is always direct and simple. No alliterations, figures of speech, enigmatic expressions, long compounds and the like, which characterise works on ornate poetry and prose, as also philosophy and religion, do not figure in science. It is presented in such a manner that even a novice in the language could understand it correctly.

A feature that makes the study of Indian science easy is that most of the technical terms are formed from well-known common place words, just with some aspect of the meaning stressed, so that there will be no need to 'learn' new technical terms but just to identify the terms on the basis of the already known words. For instance, in Astronomy:

Bhāga or part is degree (part of a circle): *Antyabhā* or last star is *Revatī* (which is the last star); *Cāpa* or bow is *Ara* of a circle (which is shaped like a bow), *Bhūmi* or Earth is horizontal; *jyā* or bowstring is Chord (in a circle) which in like the bowstring.

In view of the above and other similar factors, it is no wonder that Sanskrit had been adopted as the language of Indian Science. Thus, practically every science text produced in ancient and medieval India had been couched in Sanskrit, the exceptions being just a few texts in *Prākṛta* composed by Jain authors and another few in *Pāli* by Buddhist authors, both on the disciplines of Mathematics and Astronomy, against the avalanche of texts composed in Sanskrit.

Methodology in Sanskrit Texts on Science :

A matter that is hardly taken note of by modern students of science texts is that certain methodologies, termed *Tantra-yukti*s, had been kept in view by Indian scientists while composing their works. These conventional methods have been enunciated, illustrated and explained in certain texts, including the *Caraka-saṃhitā*, *Suśruta-saṃhitā*, *Aṣṭāṅga-hṛdaya*, and *Viṣṇu-dharmottara Purāṇa* and also in a work entitled *Tantra-yuktayaḥ* by Nīlameghācārya, besides the well-known *Arthaśāstra* of Kauṭilya of the 4th century BC. (Ed. R.P. Kangle, Bombay University, 1969).

These *yukti*-s listed by Kauṭilya in Sec. XV of the *Arthaśāstra* are enumerated below in order to demonstrate how analytic and methodical was the approach of the ancient Indian Scientists had been in presenting their compositions.

1. *Adhikaraṇa* (topic, its title)
2. *Vidhāna* (statement of contents)
3. *Yoga* (employment of connected words)
4. *Padārtha* (meaning of words)
5. *Hetvartha* (reason for establishing something)
6. *Uddeśa* (mention)
7. *Nirdeśa* (explanation)

8. *Upadeśa* (advice)
9. *Apadeśa* (reference)
10. *Atideśa* (application)
11. *Pradeśa* (indication)
12. *Upamāna* (analogy)
13. *Arthāpatti* (implication)
14. *Saṃśaya* (doubt)
15. *Prasaṅga* (situation or context)
16. *Viparyaya* (contrary, corrollary)
17. *Vākyaśeṣa* (Completion of the sentence)
18. *Anumata* (agreement)
19. *Vyākhyāna* (emphasizing)
20. *Nirvacana* (derivation)
21. *Nidarśana* (illustration)
22. *Svasaṃjñā* (one's own technical term)
23. *Apavarga* (exception)
24. *Pūrvapakṣa* (prima-facie view)
25. *Uttarapakṣa* (correct view)
26. *Ekānta* (Invariable)
27. *Anāgatāvekṣaṇa* (reference to a future statement)
28. *Atikrāntāvekṣaṇa* (reference to a past statement)
29. *Niyoga* (restriction)
30. *Vikalpa* (option)
31. *Samucchaya* (combination)
32. *Ūhya* (what is understood)

It is not as if every item in the above list should have to be applied in the case every work, nor in the same sequence. It only means that these are the methods of representation of ideas in a work and shall have to be made use of appropriately as required in a context. It has also to be noted that the *Arthaśāstra* takes one full section to illustrate and explain the above methods. Obviously, such analytic delineation of the methods of presentation of texts reflects the mental working of the ancient Indian Scientist in the presentation of his text.

Wealth of Science Texts in Sanskrit

What is, however, most interesting and important in this context is to have the realization about the wealth of science texts in Sanskrit. It might be astonishing to learn that hundreds upon hundreds of texts have been written in the land, in the several scientific disciplines. To bolster this statement, one might refer to the survey entitled *Science Texts in Sanskrit in the Manuscripts Repositories of Kerala and Tamilnadu* authored by the present writer and published by the Rashtriya Sanskrit Sansthan, New Delhi (2002). The results brought out by this survey are as much instructive as they are revealing. In this survey, which took more than two years, 1997 and 1998, to complete; about 400 manuscripts repositories, private and public, holding, in all, about one and half lakhs of manuscripts, were examined, either personally or through their available printed catalogues and hand-lists. Of these one and a half lakh manuscripts, about 12,250 were science manuscripts, containing about 3500 independent science texts in Sanskrit. It was also ascertained that of these 3500 texts about 230 or 7% had already been set to print. If this survey is taken to represent also the other regions of India, it would mean that scholars and historians of Indian science had all along been wallowing, taking 7% of texts as the whole and sole of science texts produced in the land, oblivious of the fact that 93% of the texts produced in India are secreted in their manuscript form in manuscripts repositories all over the land.

Solution to the Problem

This ignominious and shameful situation has got to be remedied. It is now up to institutions and individuals, and, in particular, scientists, both of the orthodox and the modern schools, to rise to the occasion and find ways and means in the matter of editing these manuscripts for their study.

Revision of Yugas and yuga-constants in Indian Astronomy*

Among the historians of Indian Astronomy, John Bentley seems to be first to stress, nearly two hundred years ago, that *Yuga* and *Kalpa*, which form the basic time-divisions used for traditional Astronomical computations in India, are not historical but Astronomically interpolated. Bentley says that a division of time simply into the four *yugas,* viz. *Kṛta, Tretā, Dvāpara* and *Kali*, was introduced in 204 B.C.. " It appears, as Bentley surmises, that at, or about this period (204 B.C.). improvements were made in Astronomy; new and more accurate tables of the planetary motions and positions were found, and equations introduced. Beside these improvements, the Hindu history was divided into periods, for chronological purpose. . . . . The period immediately preceding the inventorwas called the first, or *Kali Yuga*; the second or next, was called the *Dvāpara Yuga*; the third was called the *Tretā Yuga* and the fourth, or furthest back from the author, was called *Kṛta Yuga* and with which the creation began. The end of the first period, called *Kali* was fixed by a conjuction of the Sun, Moon and Jupiter, in the beginning of cancer, on the 26th June 299 B.C. This was called the *Satya Yuga,* or true conjuction, and is the radical point from which the calculation proceeds." (Bentley, 1823, pp. 61-62).

Bentley then asserts that the *Kalpa* division of time was introduced in A.D. 538, and adduces a fantastic reason for the innovation. About the epoch commencing with A.D. 538, he says, "This epoch is one of greatest importance, . . . as it was now that means were adopted by the Brahmins for completely doing away their ancient history and introducing the periods now in use; by which they threw back creation to the immense distance of 1,97,29,47.101 years before Christian era, with a view no doubt, to arrogate themselves that were the most ancient people on the face of the earth.

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The various means or contrivances that were adopted for this purpose will now be explained :- In the first place, they were made choice of a period of 4.32,00,000 years, which they called the *Kalpa*. This period they divided and subdivided into lesser periods, which the better to answer their purpose, they called by the same names of the periods of the two former divisions of the Hindu history were desiganted (viz. *Kṛta, Tretā, Dvāpara* and *Kali*), in order that they might be concieved to be the same". Bentley continues: "Matters thus far settled, the next step was to ascertain by computation, a point of time from which the calculation of the length of the year and the mean motion of the planets should proceed in order to determine the number of revolutions in each *Kalpa*, preparatory to their application to astronomical purposes. The only point of time they could find to answer this purpose was the 18th February, in the year 1612 of the Julian period, and this point they made the commencement of the *Kali Yuga*, of the 28th *Mahā Yuga*, of the seventh *Manvantara*." (Bentley, 1823, pp. 69-71).

Bentley proceeds to state : "The point of time thus fixed on was found by computation made backwards, which showed that the planets were approximating to a mean conjunction in the beginning of the sidereal sphere commencing with lunar asterism *Aśvinī*, on which account it was made choice as the point to proceed from, for, had the approximation of the planets been in any other part of the heavens, it would not have answered their purpose; because their object was to assume the sun, moon and all the planets to be then in a line of mean conjunction in the beginning of *Aśvinī*, or the sidereal sphere, in order that from that assumption, as if it had been an actual observation, they might determine the length of the year and mean motions of planets, sufficiently near the truth to answer their purpose." (Bentley 1823, pp. 71-72).

Bentley's prejudices and insinuations apart, and also his way of putting the cart before the horse by proposing that the length of the *Kalpas* and *Yugas* was decided upon first and then only a particular date in the first year of *Kalpa* or *Yuga* was sought for answering certain specifications, instead of the other way, his line of agreement would be clear from the above.

Roger Billard (1971, p. 222), in his recent work, *L 'astronomie indienne,* and also elsewhere, ascribes the introduction of the current concept of the four *yugas* to Āryabhaṭa (born A.D. 476). Billard says: Not only did Āryabhaṭa construct *Yuga* upon such beautiful reduction of observations, but I must add that almost certainly the great astronomer is also responsible for the very introduction of the *yuga* speculation into mathematical astronomy.

Prof. T.S. Kuppanna Sastry observes on this point: "All scholars agree that the mean sun and moon are at the zero point of Aśvinī at the above mentioned *Kali* epoch. Excepting school No. (3), the others are also agreed that the mean planets too are at that point at the Epoch and that are moon's apogee is 90° and the node 180° from that. What are we to understand fro this? Are we to think that at such an ancient date as 17/18 February 3120 B.C. the Hindu astronomers gave this result as got from their observation? Or, was this point of time fixed by some later astronomers as convenient epoch for starting their calculation? The former alternative cannot be accepted, because the mean sun, moon and planets were not the same but differed widely from one another, nor were they at zero Aśvinī as calculated by modern astronomy for that epoch. Scholars like Bentley first conceived this idea of verification by calculation. Bentley showed that starting from the epoch and working by each *Siddhānta* , the error gradually became less, until at the time of the later *Siddhāntas*, the error became a minimum, as must be expected. Thus, he proved that the second alternative was the correct one, and that the Kali era starting from this epoch was an axtrapolated era founded by astronomical *siddhāntas*". (Sastri, 1974, p. 34).

With regard to original Sanskrit texts, normally one cannot expect them to go into the rationale or the justification or otherwise of the traditionally accepted concepts of Ikalpa *and* Yuga. It has however been possible to identify a few texts which categorically state about these concepts being of an interpolated nature. For instance, the Kerala astronomer Putumana Somayāji, mentioning the different *Yuga* divisions adopted by different schools, asserts that these *Yuga* - measures have been concieved only as a means of computation to arrive at correct results. Thus, he states :

कल्पादीनां प्रमाणं तु बहुधा कल्प्यते बुधैः
उपेयस्यैव नियमो नोपायस्यति यत् ततः ।। (करणपद्धति ५,१५)

He then proceeds to recount the different scholars.

कल्पे युगानि सहस्रम् उशन्ति केचित् ।
तत्रैकसप्तति युगानि पृथङ् मनूराम् ।।
आद्यन्तयोश्च विवरे च तथैव तेषाम् ।
स्युः सन्धयो युगदशांशचतुष्कतुल्यः ।16।
मनवोऽथ चतुर्दशैव कल्पे।
पृथुतुल्यानि युगानि चैव तेषाम् ।
त्रियुगानि गतानि सृष्टितः प्राक्
परतः स्युः प्रलयात् तथाहुरन्ये ।17।
युगस्य दशमो भागो भो-ग-प्रि-य-हतः क्रमात् ।
कृतादीनाम् प्रमाणं तु स्यात् पक्षयोरन्ययोः द्वयोः ।18।
कल्पेऽस्मिन् सप्तमस्यास्य वैवस्वतोर्मनोर्युगे ।
अष्टविंशे कलिः सर्वैर्वर्तमान इह स्मृतः ।19।z

"The measures of *Kalpa* etc. have been concieved by the (ancient) authorities differently, for, it is only the result that counts, not the means." (*Karaṇapaddhati*, 5.15)

"Some (Like *Sūryasiddhānta,* Bhāskara II etc.) take the number of *yugas*, there are (in all fifteen) contact periods, each equal to four-tenths of a *yuga.*" (16).

"Still others say that the number of *Manu* period in a *Kalpa* is only 14, each having 71 *yugas*, but that 3 *yugas* have passed by before Creation and 3 *yugas* will occure only after Dissolution". (17)

"According to the above two views, the measure of the *Kṛta* (*Tretā, Dvāpara* and *Kali yugas*) are in proporation of 4,3,2 and 1 tenth parts of the (*Caturyuga)*". (18)

"All agree that today, the current *yuga* is *Kali* in the 28th *Caturyuga* of the 7th *Manu* (viz. *Vaivasvata manu)* in the present *Kalpa.*" (19)

About Āryabhaṭa's concept of the *Yuga* , which is different from the above, our author says:

कृत-त्रेता -द्वापराख्याः कलिश्चैते युगाङ्घ्रयः ।
युगाङ्घ्रयस्तु कल्पेऽस्मिन् धिगादित्यमितागताः । (करणपद्धति 1.7)

"(According to Āryabhaṭa), (the measures of) each of the four *yugas* , *Kṛta, Tretā, Dvāpara* and *Kali* (are equal, being) one-fourth of the (*Catur-*)*yuga* . In the current *Kalpa,* 1839 quarter - *yugas* are gone !"

(*Karaṇapaddhati*, 1.7).[1]

Whatever be the *yuga*-concept adopted, astronomers stress that the computed result should accord with observation. Thus another Kerala astronomer, Parameśvara (1380-1460, states, in his *Sūrya-siddhāntavivaraṇa* (Shukla, 1957, p. 21), under 1.66.

ग्रहाणामत्र सिद्धानां दृग् भेदो दृश्यतेऽधुना ।
दृग् भेदहेतुः कोऽत्र स्याद् अस्माभिरिति चिन्त्यते ।।
अव्यवस्थिता तु खेटानां भुक्तेरिव हि युज्यते ।
शैघ्र्यं मान्द्यं तथा कल्प्यं क्रमादेव गतेस्ततः ।।
कालतो गतिभेदाच्च सिद्धान्ता बहुधा कृताः।
ब्रह्माद्यैरित्यतः सिद्धां भेदोऽतस्तेषु युज्यते ।।
तत् तत् काले गतिवशाद् अनुमानेन कल्पिताः ।
भगणास्तैर्निजानिजे सिद्धान्ते सिद्धमित्यपि ।।
दृश्यमानोऽधुना तेषां दृग्भेदः सृष्टिकालतः ।
ऊर्ध्वकालेन सञ्जात इति कल्प्यं बुधैरतः ।।

"There is found difference between the (longitudes of) planets as computed and as observed at present. I am discussing as to what could be the cause of the siad difference in the observed positions."

"Variation in the planets can be assigned only with regard to their rates of motion. Hence, increased fastness or slowness, as the case may be, shall have to be presumed in the rates of motion of the planets. "

"It is, therefore, only proper that a number of *Siddhānta* texts have been produced by Brahmā and others on account of their differences (form one another) in the matter of the time (of their production) and the then rates of motion of the planets."

"Hence it is also proper that the number of *yuga* - revolutions are determined through deduction from the rates of motion at specific times, for the different *siddhāntas.* "

"It again, stands to reason to ascribe the differences that are now observed in the planetary positions to this having developed differences in their rates of motion during the passage of time from creation to the present time ."

In the verses following, this author has worked out the actual positions of the planets that would have been occupied by them at the beginning of *kali,* on the basis of the current rates of their motion and has given the results as zero corrections to *kali* beginning.

. Another astronomer who has expressed similar views is Śaṅkara Vāriyar (1500-60), who, in his commentary *Yuktidīpikā* (Sarma, 1977, p. 73) on the *Tantrasaṅgraha* of Nīlakaṇṭha Somayāji, 1.35, states :

कालादौ न निरंशत्वं भगणादेर्द्युचारिणाम् ।
गतिभेदात् तु दृक् सिद्धास्तत्रैषां स्युर्ध्रुवास्ततः ।।

"At zero *Kali*, the revolutions etc. of the planets cannot (be taken to commence from their zero positions on account of the (subsequent) change of their velocities. Therefore, zero corrections should be set for them as calculated from their currently observed positions."

In his *Karaṇapaddhati,* Putumana Somayāji not only states the necessity of revising, suitably, the *yuga* - revolutions and other constants, but sets out the methods therefore :

ग्रहणग्रहयोगाद्यैर्ये ग्रहाः सुपरीक्षिताः ।
दृक् समस्तत् समः कल्पे कल्प्या वा भगणादयः ।। 5.1 ।।
परीक्षितस्य खेटस्य तन्त्रानीतस्य चान्तरम् ।
लिप्तीकृत्यर्कभगणैः कल्पोक्तैश्च समाहतम् ।। 5.2 ।।
तन्त्रनिर्माणकालस्य परीक्षासमयस्य च ।
अन्तरालगतैरब्दै राशिचक्रकलाहतैः ।। 5.3 ।।
हत्वाप्तं तत्रानीतस्य ग्रहस्याल्पाधिकत्वतः ।
स्वर्णं तत् कल्पभगणे कुर्यान्नैष विधी रवेः ।। 5.4 ।।

"(The number of) planetary revolutions (taken to constitute) a *Kalpa* (according to the *siddhānta* taken up for consideration) should be revised (periodically) so that eclipses and planetary conjunctions computed using those numbers would accord with observation." (5.1)

"(Towards effecting such revision) take the difference between the true positions of a planet as observed (in the sky) and as computed using the number of revolutions (enunciated in the *Siddhānta*) and reduce the difference to minutes. Multiply this by the Sun's *Kalpa* revolutions of the *Siddhānta* (or other text) at which time of the composition of the *Siddhānta* (or other text) at which time it is to be presumed that the computation accorded with observation). Reduce the quotient (which would be in full cycles) to minutes by multiplying it by 21,600 (being the number or minutes contained in a cercle)". (5. 2-3).

"The result (which is the correction in terms of revolution) is to be added to or subtracted from the number of the (currently accepted) *Kalpa* revolutions (enunciated in the *Siddhānta* or text) according as the true planet determined by computation is less or more (than the observed true planet). This mode of correction is not to be applied to revise the Sun's revolutions (since the basis itself of the correction is the sun's revolutions). (5.4).

The above discussion is a pointer also to the fact that astronomical science in India had not remained stagnant and static as is generally supposed and often alleged. It had been evolving, in a particular manner, continually in different spheres and at different levels.

NOTES :

1. 1839 quarter *Yugas* would amount to 6 *manus,* 27 full *Yugas* and 3 quarter *Yugas,* the quarter *Yuga* current today being of *Kali yuga* in the 28th *Manu* period, in consonance with the other schools. There is still another *Pañcasiddhāntikā* of Varāhamihira, followed also by the midnight system of Ārtyabhaṭa and the *Khaṇḍakhādyaka* of Brahmagupta.

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THE ŚAKA ERA OF VARĀHAMIHIRA: ŚĀLIVĀHANA ŚAKA*

Introduction

With reference to chronology the word '*Śaka*' is used in two senses: (1) As a common noun meaning any era (as for e.g., in the terms *Yudhiṣṭhira Śaka. Vikrama Śaka, Mālava Śaka, Śālivāhana Śaka* etc.) and (2) As a proper noun to mean a particular era called the *Śaka-kāla* or *Śaka* Era. Most Indologists believe that the *Śaka* Era is the same as what later is generally referred to as the *Śālivāhana Śaka* which commenced with the month of *Caitra* occurring in 78 A.D., i.e. at the end of 3179 years of the *Kali* Era; for it can be shown that all astronomical works and commentaries thereon, wherever they mention a *Śaka* Era mean only the *Śālivāhana* Era, starting, as mentioned above, from 3179 *Kali* elapsed. But some like the late T. S. Narayana Sastri,[1] Prof. Gulshan Rai,[2] Kota Venkatachelam,[3] and Prof. V. Thiruvenkatacharya[4] (VT) take the work to mean a certain Cyrus Era or *Āndhra* Era, which they say, started from 550 B. C.[5] Still another view is expressed by Sri. K. Rangarajan, who takes it to mean an era which commenced from 523/22 B. C. with the first Viceroy of India appointed by the Persian Emperor.[6] They also try to show that it never means the *Śālivāhana Śaka.*[7] What astounds us is that even where there is clear evidence that *Śālivāhana Śaka* is to be taken, (in the shape of statements that 3179 is to be added to the years gone in the *Śaka Era* to get the years gone in *Kali*)[8] these scholars ignore it implicitly or explicitly as in the case of the *Śaka-kāla* mentioned by Brahmagupta and Bhāskara II.[9] When this is the fate of such clear evidence, we need not be surprised if they identify with their alleged Cyrus or Andhra Era, the *Śaka Era* mentioned in giving the epochs of *Karaṇas* (astronomical manuals) as in the case of the *Pañcasiddhāntikā* (*PS*), the *Khaṇḍakhādyaka* or the *Laghumānasa* or in giving the date of a work given by the author, as for instance by Bhaṭṭotpala at the end of

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his commentary on the *Bṛhajjātaka* or in inscriptions like the Aihole Inscription, or in other sundry places as in the *Bṛhatsaṃhitā* I.13, in all of which cases the identification has got to be made by examining the months and *Tithis* and *Kṣepa*s mentioned therewith.

The reason why they want to identify the *Śakakāla* with the so-called Cyrus or *Āndhra* Era is this: They believe that there was a "Plot hatched by European Indologists" to post-date by several centuries the ancient events of Indian History, and that most Indian Indologists have become unconscious victims of that plot. They try to show that the *Yudhiṣṭhira* and *Saptarṣi* Eras are everywhere identical, and were actually started 25 years after the beginning of the *Kali* Era. Using this they try to show that it is Samudra Gupta of the Gupta dynasty that is to be identified with the Sandracottus of the Greeks, and not Candragupta Maurya, which latter identification has been taken by the European Indologists as the sheet-anchor of Indian chronology, and the chronology of the dynasties before and after that time is established. Now the identification of *Śakakāla* with *Śālivāhana Śaka* stands in their way. Hence their attempt to identify it with the so-called Cyrus or *Āndhra* Era whose very existence is a matter of dispute, there being no evidence for it.

Most historians have not taken these people seriously, thinking that the very extravagance of their claims would be a deterrent to the acceptance of their views. But attempts have been made by Professor Gulshan Rai and VT to give astronomical and mathematical proofs to show that Varāhamihira (VM) belongs to 123 B. C. and not to 505 A.D. (as he is generally believed to be), and thereby that the *Śakakāla* mentioned by VM is the Cyrus or *Āndhra* Era.[10] They also attempt to show that the *Śakakāla* mentioned by Bhaṭṭotpala as stated above is the Cyrus or Andhra Era, and therefore the *Śaka* year 888 given by him corresponds to 338 or 339 A.D.;[11] Which would mean that Brahmagupta, Āryabhaṭa, Bhāskara I etc. must precede this date, as explained below in this article. The present article is intended to expose the hollowness of the above theory and to show that the astronomical arguments adduced in support of it (which to the lay reader may look

formidable) are erroneous, and thus knock the bottom out of the claims of this set of writers.

Varāhamihira used the word *Śakakāla* in two places in his works.

(1) In the *Bṛhatsaṃhitā* he says:

āsan maghāsu munayaḥ śāsati pṛthvīm yudhiṣṭhire nṛpatau ।
ṣaḍ-dvika-pañca-dvi-yutaḥ śakakālas tasya rājñaś ca ॥ XIII. 3.

"The *Sapta-ṛṣi*-s were in the asterismal segment *Maghā* when Yudhiṣṭhira was ruling over the earth. Any date by the *Śaka* Era plus 2526 gives the date in the *Yudhiṣṭhira* Era."

(2) In his *PS* the following occurs:

Sapta-aśvi-veda-saṅkhyām śakakālam apāsya caitra-śuklādau ।
Ardhāstamite bhānau yavanapure somadivasādyaḥ ॥ I. 8 ॥[12]

"Deducting 427 from the *Śaka* Era, at the beginning of the light half of Citra, which falls near sunset at Yavanapura, beginning a Monday ..."

In (1) a synchronism is found between the *Śaka Era* and the *Yudhiṣṭhira Era.* I shall not discuss this synchronism here but rest content with saying that whatever be the *Śakakāla* mentioned in no. 2, it is highly probable that the same is mentioned in 1. In 2, it is clear that the epoch of the *Pañcasiddhāntikā* is as given 427 *Śaka* elapsed, which means the date of the work must be c.427 *Śaka,* and thus VM's time can be fixed. If as VT and others say the *Śakakāla* meant here is the Cyrus or *Āndhra* Era of 550 B. C., then the date of VM must be 427 years after 550 B. C., i.e., 123 B. C., which Gulshan Rai and VT have tried to establish by their special arguments. If it is the same as the *Śālivāhana Śaka,* then VM's date must be 427 years after 78 A.D.,i.e., 505 A.D.

Here we do not propose to go into the question whether there was a *Śaka* Era beginning from 550 B. C. or whether it is necessary to

postulate such an era in view of the reference in the *Bṛhatsaṃhitā śloka* quoted above. We shall confine ourselves to show that the *Śakakāla* of VM's *PS* is the *Śālivāhana Śaka*, and therefore 427 *Śaka* (elapsed) corresponds to 505 A.D. As we have stated before, we shall also show that the special arguments to the contrary advocated by Gulshan Rai and VT and their conclusion that VM's date is 123 B. C. cannot stand.

Internal Evidence for *Śālivāhana Śaka* :

There is plenty of internal evidence to show that the date meant by VM is 505 A.D. and not 123 B. C. It consists of the many *Kṣepas* (Values of the Mean longitudes etc. at Epoch) found in the work, and the names of certain authors which it mentions. We shall take to *Kṣepas* first.

In *PS.* I.14, VM gives a *Saura* period of 1,80,000 years or revolutions of the Sun, in which there are 66,389 intercalary months and 10,45,095 suppressed *tithis.* From this we can get that there are in this period 2,406,389 revolutions of the Moon and 65,746,575 civil days. Comparing this with the *Yuga*-elements derivable from the *Khaṇḍakhādyaka*[13] of Brahmagupta (which follows the *Ārdharātrika* system of *Āryabhaṭa* and whose elements are identical with those of a *Pauliśasiddhānta* quoted by Bhaṭṭotpala in his commentary of the *Bṛhatsaṃhitā*),[14] - not the *Pauliśa* of the *PS* - we find that this is only a sub-*yuga* forming a twenty-fourth part of the *Yuga* given by them, and this suggests that the *yuga*-elements of the original *Saurasiddhānta*, of which the *Saura* of the *PS* is a compendium, are identical with those of the *Khaṇḍakhādyaka* etc. mentioned above. These elements, therefore, may also be called hereafter, the *Saura* elements. Now all these systems have arrived at 0^0 mean longitude fro the Sun, Moon, Mars etc., 3 *rāśis* for the Moon's *ucca* (Apogee), and 6 *rāśis* for *Rāhu's* head (Moon's Ascending Node), at the beginning of *Kali* yuga, viz., midnight at Ujjain, Thursday/Friday, 17/18, February, 3102 B. C. Taking that *Śaka* 427 mentioned in *PS.* I.8, refers to *Śālivāhana Śaka* 427, (equivalent to 3606 Mean Solar years after the beginning of *Kali*), we

have 1,317,123 days, 3 *nāḍis*, 9 *vināḍis* gone in *Kali*, and arrive at 3 *nāḍis*, 9 *vināḍis*, after the midnight at Ujjain, Sunday/Monday, 20/21 March 505 A.D.[15] The *Saura* of the *PS* takes this midnight as the Epoch for the computation of its Star-planets (*tārā-grahas*), viz., Mars etc. If we compute the Mean mars etc. for this epoch, using the *Saura* elements, the results agree with the respective *Kṣepas* given in the *PS* to the second in the case of Jupiter and Saturn, within 4" in the case of Mars and Venus, and 7" in the case of Mercury. Even this small difference is due to VM having arrived at the *Kṣepas* using the shortcut given by him in the *Karaṇa* and the number of days gone in *Kali* as the *Ahargaṇa* (days from epoch).[16] If we do the same there is complete agreement in the case of Venus also, and the difference is reduced to 2" in the case of mars. In the case of Mercury there is difference of a few seconds still, which may be due either to VM desiring to give its *Kṣepa* correct to the minute only, or to some defect in the manuscript reading which has omitted the seconds; and one of the manuscripts has actually a reading '*vilipti*' here.[17] For the Mean Sun and Moon, and the Moon's '*Ucca* and *Rāhu,* the epoch taken is the Midday at Ujjain just preceding the epoch of the Star-planets, i.e., the midday of Sunday.[18] Here too, checking the *Kṣepas* in the manner given for the Star-planets, we find perfect agreement in the case of the Sun and Moon, and agreement within 4" in the case of the *Ucca*. In the case of *Rāhu* the available manuscripts are so vitiated that Thibaut and Sudhakara Dvivedi (T-S) have failed to give the *Kṣepa* fully. Using the letters available in the manuscripts, the relevant verse may be read as:

trighanaśataghne navakaikapakṣarāmendudahanaṣaṭsahite I
svarayamavasubhūtārṇavaguṇadhṛti-bhakte kramād rāhoḥ II

PS. IX. 6.

The *Kṣepa* for *Rāhu* enunciated in this verse as reconstructed above, agrees within 1" with its value according to the *Khaṇḍakhādyaka* elements.[19]

This perfect agreement is the reason why S. B. Dikshit has retained the date March 505 A.D. in spite of the difficulties he encountered in interpreting *PS* I.8 with reference to the *Saura.*[20] For, no

date, within many thousand years before or after 505 A.D. will agree with the *Kṣepa*s in the manner shown above, not to speak of 123 B. C. When such is the case, VT quoting from Dikshit,[21] a passage, which to those that have not read Dikshit's article in full will appear to involve an irremediable contradiction, says that 505 A.D. should be abandoned in favour of 123 B. C. on account of this. As the manner of VT's quoting[22] from the article may create an impression in the readers' mind which Dikshit did not intend, and as VT himself concludes from the quotation that the agreement in the *Kṣepas* discovered by Dikshit is null and void, and as he does not realise (as seen from his remarks under the quotation) that if he gives 123 B. C. for VM, he still has the responsibility to point out that the *Kṣepas* agree with his date, we intend making the discussion a little elaborate so that we may give Dikshit's views in full with some pertinent observations on them.

The *Saura* Epoch occurs before the True *Vaiśākha śukla pratipad,* ending on Tuesday. Dikshit wants to reconcile this with the statement in *PS* I.8, *Caitra-śuklādau.* He considers the point that according to Mean reckoning, it is '*Adhika*' *Caitra Śukla*, but dismisses it, giving two objections: **i.** Why does not VM use the term *'adhika-caitra-śuklādau'*? **ii.** Why should he take the *Adhika Caitra* instead of the regular *Caitra* for the Epoch?[23] Dikshit concludes by saying that '*caitra-śulklādau*' might stand, because *amānta-vaiśākha-śukla* in *caitra-śukla* according to *pūrṇimānta* reckoning. So there is no trouble at all for Dikshit as far as this goes. Therefore there is no need for VT to abandon 505 A.D., go to 123 B. C. and show that the *caitra śukla pratipad* of this year occurs on a Wednesday, which weekday also is admissible according to one manuscript reading.[24] (*Cf.* the readings given above). It should be remembered that VT can score a point only if the weekday, viz. Wednesday of the *Caitra Śukla Pratipad* of 123 B. C. alone can effect the reconciliation, and not the Tuesday of the *Caitra Śukla Pratipad* of 505 A.D.

But really speaking, there is no need to reconcile the *Saura* with any part of *PS* I. 8, because it has reference only to the *Romaka*

and the *Pauliśa* (If it can be applied to the *Saura* also, as indeed it can, it is good, but we have no right to demant it as Dikshit does.).[25] *PS*. I.8-10 give the computation of *Ahargaṇa* according to the *Romaka*; and I.8 and 11 (and perhaps also 12 and 13) according to the *Puliśa*, 1.8 gives the Epoch, which is thus the same for both. The Epoch is the beginning of *Caitra śukla* which ends 427 *Śaka*, and the exact time is sunset at *Yavanapura*[26] beginning Monday, i.e., 7 *nāḍis*, 20 *vināḍis* after sunset at Ujjain. This is equivalent to 37 *nāḍis* 20 *vināḍis* after Ujjain sunrise on Sunday, 20th March 505 A.D. The *Ahargaṇa* with which to compute the Mean Sun etc. must be reckoned from this point for *Romaka* and the *Pauliśa*, and their *Kṣepas* are for this point. The expression '*Caitra-śuklādau*' is an indication that the months gone are to be counted from *Caitra* in computing the *Ahargaṇa*, and the words 'beginning Monday' is a check for the *Ahargaṇa*, Monday being stated to be the first day of the *Ahargaṇa*. For, the *Ahargaṇa* got by computation may be a day more or less than the correct one (a fact wellknown to astronomers) because the '*varying*'. True *Tithi* has got to be used in the formula; and checking by Monday beginning from the Epoch, viz., 0 *Ahargaṇa*, it may happen that one day has got to be added or subtracted. This can be made clear by an example.

Problem: What is the *Ahargaṇa* for Saturday beginning, next to the Epoch? By counting we see we must get 5 days for *ahargaṇa*. Let us now compute it. By the *Romaka* or *Pauliśa* (or even *saura*) almanac, the *tithi* gone at Saturday beginning is *caitra śukla caturthi*. Using it in the above formulae enunciated in *PS*. I. 8-11, 4 is got as *ahargaṇa*. But counting from Monday, 4 will give only Friday beginning. So we must add 1, and give 5 as the correct *ahargaṇa* if it should agree with Saturday beginning. We see here the use of the check. This is the purpose for which the weekday beginning the Epoch is given, and not to satisfy the curiosity of the reader. From this we can see that 'Monday' is necessary, and 'Tuesday' or 'Wednesday' will be wrong. So in *PS* I.8,'*soma-divasādye*' or '*soma-divasādyaḥ*' must have been VM's original reading. '*Bhaunma*' must have been a scribal error, or the correction of some revisor who did not understand what was necessary, but thought that the weekday of the *True Śuklapratipad*

gone must be given here, and this must have given rise to '*saumya*', a mixing of the two. Here T-S have rightly given the emendation '*soma-divasādye*'. I may venture to give another suggestion, even if it may not appear very convincing to some. The emendation of T-S is not really essential and we can adopt the manuscript reading '*saumya*' as such and take it in the *yaugika* (dirivative) sense, meaning 'day pertaining to the Moon', i. e. Monday. Though there is the dictum '*rūḍhir yogam apaharati*' (the meaning obtained by usage is stronger than that got by derivation), still at such an ancient period as VM's, when the weekdays must have come into use very recently, the word *saumya-divasa* might not have become *rūḍha* in *budha-vāra* as it is now. Also when other things require the derivative sense, we are permitted to abandon the *rūḍha* sense.

The above discussion has been necessitated here by a desire to remove any doubt created in the readers' minds by Dikshit's dissatisfaction, which may be interpreted as going against the case for 505 A.D.[27]

We may now proceed to show that the *Kṣepas* of the *Romaka* and the *Pauliśa* also, as well as the *Adhimāsa* and *Avamaśeṣas* of their rules for *Ahargaṇa*, agree with 505 A.D. and not with 123 B. C. We have seen that the Epoch for the *Romaka* and *Pauliśa* is 37 *nāḍis,* 20 *vināḍis* from sunrise at Ujjain on Sunday, 20 March 505 A.D. (It must be noted that Dikshit does not question this.). The *Romaka* Mean-Sun at Epoch can be seen to be 359^0 341/2, by taking the *Ahargaṇa* as zero in *PS* VIII.1, and working with the *Kṣepa* left. This means that 26 *nāḍis* after Epoch, the Mean Solar month *Meṣa* begins. In the same way we get the Mean Moon at Epoch from *PS* VIII.4, to be $356^0 12'$, using the emended reading '*kṛtāṣṭanavakaika*'; if the reading '*kṛtāṣṭanavakaika*' found in the manuscript and followed by T-S, and Dikshit is used, it is 359^0 19 at Epoch for T-S and 2^0 24' for Dikshit who takes that the Moon is given for sunset at Ujjain. From this we see that the Mean New Moon according to our interpretation will take place at 16 *nāḍis,* 36 *vināḍis* after Epoch, i.e., 9 *nāḍis*, 24 *vināḍis* before the Mean-Sun comes to *Meṣa*. According to T-S's value for Moon, it is 24

nāḍis, 42 *vināḍis* before the Mean Sun at *Meṣa;* and according to Dikshit, 32 *nāḍis*. It must be noted that according to all the three interpretations, the Mean New Moon just precedes the Mean Solar year; i.e., the New Moon end begins the Mean *Caitra* and is very near the Epoch.[28] The corresponding *Kṣepas* of the *Pauliśa* also will be found to give the same result. Thus the word *Caitra* in *PS* I.8 presents no difficulty, as it is mentioned only in relation to the *Romaka* and the *Pauliśa*. Also the *Avama* and the *Adhimāsa Śeṣas* of the *Romaka* and the *Pauliśa* found in *PS*. I. 9-11, agree, within the limits of accuracy, with the time of the day when the respective New Moon occurs, and its distance from the beginning of the Mean Solar year as found from *PS* VIII and III. From the foregoing facts we see that the beginning of *Caitra* should fall very near the beginning of the Mean Solar year, which it does if we take 505 A.D. If 123 B. C. is taken, it is about 20 days away, and so there is disagreement with the *Kṣepas* of *PS* I.8-11, and those of the Sun and the Moon in *PS* III, VIII and IX.

In the case of the *Saura*, and examination of the Sun's and Moon's Kṣepas given in *PS* IX..1-2 will show that the Mean Solar year ends at 3 *nāḍis*, 9 *vināḍis* after midnight, Sunday/Monday, 20/21 March (as we have already shown) and the Mean New Moon falls about 12 *nāḍis*, 30 *vināḍis* after the Mean Solar year. Thus there is a Mean *Adhimāsa* following the Epoch of the Star planets, i.e., midnight, which can be called *Caitra*, as Dikshit himself has accepted.[29] As it is very close to (i.e. only 12 *nāḍis*, 30 *vināḍis* from) the beginning of the Mean Solar year, and as in computing the *Ahargaṇa* the practice is to see whether an *adhimāsa* has taken place or not in the months gone used for reckoning, and adjust the number of *adhimāsas* got by adding one or reducing the *Adhimāsas* by one, by treating a large *adhimāsa-śeṣa* as unity or not counting one just got by computation, no harm will ensure if this *adhika-caitra* is treated as regular *Caitra*, taking the previous regular *Caitra* as *adhika-Phālguna*. And there is the advantage of dispensing with a Kṣepa for months gone at Epoch. So even if *PS* I.8 applies to the *Saura* as Dikshit thinks, the objection which he has to using the term '*caitrādau*' for this vanishes, and there is no need to explain it in the manner he has done.[30] Thus all the difficulties raised

by Dikshit are answered, and not a trace of any objection for 505 A.D. is left.

We may now proceed to give another piece of evidence to show that the date cannot be 123 B. C. In *PS* XV we find the *following śloka:*

> *laṅkārdharātrasamaye dinapravṛttim jagāda cāryabhaṭaḥ* I
> *bhūyas sa eva sūryodayāt prabhavṛtyāha laṅkāyām* II
> (*P.S.* XV. 20.)

Here is a reference made by VM to Āryabhaṭa and his two works, the well-known *Āryabhaṭīya,* and his less known work referred to by later authors as his '*Ārdharātrika* System', manuscripts of which are yet to be discovered, but whose nature is fully given by Bhāskara I (6^{th}-7^{th} cent.) in his *Mahābhāskarīya.*[31] In the *Kālakriyāpāda* of his *Āryabhaṭīya, Ā*ryabhaṭa says:

> *ṣaṣṭyabdānām ṣaṣṭir yadā vyatītās trayaś ca yugapādāḥ* I
> *tryadhikā viṃśatir abdās tadeha mama janmano 'tītāḥ* II
> (*Ābh. Kālakri.* 10)[32]

This says that at 3600 *Kali* (expired) Āryabhaṭa had completed twenty-three years of age, and 3600 *Kali* is 499 A.D. VM's reference is certainly to this Āryabhaṭa as can be gathered from the mention of him as the author of both the *Ārdharātrika* and the *Audayika* systems. It follows from this that VM must be later or at least a contemporary of this Āryabhaṭa. So VM can belong to 505 A.D. and not to 123 B. C. Thus all internal evidence and we have seen plenty of it-points to 505 A.D. as the time of VM.

The *Ayanāṃśa* Argument Examined :

Now Profs. Rai and VT have advanced an argument based on *Ayanāṃśa* to show that VM must be as early as 123 B. C.[33] Being interspersed with mathematics, this argument may seem unassailable to some, unless its hollowness is exposed. Being more full, we may discuss VT first. What VT says may be put succinctly as follows: (i) At

the time of VM the Summer Solstice was at the *end* of the asterismal segment *Punarvasu,* (or what comes to the same thing, the Vernal Equinox had a longitude of 3° 20' reckoned from the Zero Point of the Ecliptic), as gathered from VM's own statements in the *PS* and the *Bṛhatsaṃhitā.* (ii) Taking the *Ayanāṃśa* (i. e. the total precession) to be *zero* at VM's time, there is an *Ayanāṃśa* of 28° 15' in April 1909 A.D. (It comes to this: The Vernal Equinox has receded 28° 15' from the original position of 3° 20', and its position in 1909 is 335° 5' from the Zero Point of the Ecliptic). (iii) Using the correct rate of precession (*ayana-calana)* per annum, 50".2585 - *n* X 0".000225, where *n* is the number of years before 1909, for a precession of 28° 15' to take place *n* must be 2031 years. (iv) This means 2031 years before 1909, i.e. in 123 B. C., the *Ayanāṃśa* was zero, and therefore 123 B. C. is the date of *PS.*

We admit that if (i) and (ii) are correct, (iii) and (iv) follow automatically. But (i) and (ii) are not correct, as we shall show. Relating (i) there are the following three *śloka*s of VM, which are quoted by VT also.[34]

> *āśleṣārdhād dakṣiṇam uttaram ayanam raver dhaniṣṭhādyam I*
> *nūnam kadācid āsīd yenoktam pūrvaśāstreṣu II*
> *sāmpratam ayanam savituḥ karkaṭakādyam mṛgāditāś cānyat I*
> *uktābhāvo(?ve) vikṛtiḥ pratyakṣaparīkṣaṇairvyaktiḥ II*
> *Bṛ. Sam. III. 1-2 II*
> *āśleṣārdhād āsīd yadā nivṛttiḥ kiloṣṇakiraṇasya I*
> *yuktam ayanam tadāsīt, sāmpratam ayanam punarvasutaḥ II*
> *PS III. 21 II*

'Certainly at one time the turning of the Sun towards the south was from the middle of the *Āśleṣa* segment, and the turning north was from the beginning of the *Dhaniṣṭhā* segment, because this is mentioned in ancient works'.

'But now the turnings are from the beginning of the *Karkaṭaka* and *Makara rāśi* segments respectively. If this does not happen (in future, on account of precession), the amount of precession is to be determined by observation'. (*B.S.* III.1-2)

'When the Sun turned away south from the middle of *Āśleṣa*, it was proper for that time. But now the turning away is from *Punarvasu*'. (*PS*. III. 21).

Now in the *śloka* from the *PS*, 'from the middle of *Āśleṣā*' corresponds to the same phrase in the quotation from the *BS*. III. 1; and 'from *Punarvasu*' corresponds to "the beginning of *Karkaṭaka*" in *BS*. III.2 above, the same phenomenon of precession being described in both. So 'from *Punarvasu*' must be taken to mean a point three quarters from the beginning of the segment, for that is the point corresponding to the beginning if *Karkaṭaka*. But VT who wants the end of *Punarvasu* to be the turning point, wants us to shut our eyes to the specific reference to the 'beginning' of *Karkaṭaka*, and take it to mean 'some where'in *Karkaṭaka*, giving the reason that the word is found in a mere *Saṃhitā* and not in a *Karaṇa* like the *PS*. It seems he has not taken note of the many passages in the *PS* itself that specifies the 'beginning' of *Karkaṭaka* as the point. For instance, in the *śloka* next but one, i.e. *PS* III. 23, we find '*meṣa-tulādau viṣuvad*', 'at the beginning of *Meṣa* and *Tulā* are the Equinoxes'. One *śloka* later we have again:

> *udagayanam makarādau ṛtavaḥ śiśirādayaś ca sūryavaśitā I*
> *dvibhavanakālasamānam, dakṣiṇam ayanam ca karkaṭakāt II*
> *PS. III. 25II*

In XIII. 10, we have 'At the end of *Mithuna* the Sun revolves at the altitude of 24^0 at the N. Pole'.

Also VT says that *Punarvasutaḥ* can mean only from the 'end of *Punarvasu*'. This interpretation is wrong. It only means 'from *Punarvasu*', and can mean any point in it. *Grāmataḥ paṭṭaṇam pratiṣṭhate* does not only mean 'he starts from the border of the village'. It can mean any point in the village.

Further, the context in which *āśleṣārdhāt* etc. is found itself specifies a point 1 3/4 segments from the middle of *Āśleṣā* and this point is three quarters of *Punarvasu*. In the immediately preceding śloka, VM states that *Vyatīpāta Puṇyakāla* occurs when Sun plus Moon equals 17 asterismal spaces, i. e. 17 X 13^{0} 20', or 226^{0} 40' as opposed to our expectation that it should occur at the middle of the 14th (i.e. at 180^{0}) according to the definition given in the *Śāstras*.[35] There is a difference of 46^{0} 40' or 3 1/2 spaces that has to be explained. As *Yoga* is obtained from the combined longitudes of the Sun and the Moon, a change of 1 3/4 asterismal segments in the longitudes of each, caused by the shifting of the origin of reference will explain the difference of the 3 1/2 spaces. This shifting of the origin, by the precession of the equinoxes, is mentioned in *āśleṣārdhāt* etc., and this must be 1 3/4 segments as required, and the point at 3/4 *Punarvasu* follows for it is this point that is 1 3/4 segments behind the middle of *Āśleṣā*.[36]

Still another proof can be adduced to show that 3/4 *Punarvasu* is to be considered as the point in question. If it is the end of *Punarvasu*, the Vernal Equinox is, as I have already stated, at + 3^{0} 20' from the zero point from which the longitudes of the Sun, the Moon etc. are reckoned. So to get the declination of the Sun etc., to compute the daylight, the shadow and other things, in short for all work usually given in the *Tripraśnādhikāra* of a *Siddhānta*, we must be instructed to deduct 3^{0} 20' from the longitudes got by computation, and use this for the calculation, as the longitudes from the Vernal Equinox are to be used here. In as much as such an instruction has not been given anywhere in the text, we must take it that the zero point and the Vernal Equinox were coincident, which means that the Summer Solstice was at 3/4 *Punarvasu*. Now in (ii), VT has budgeted for an *Ayanāṃśa* of 28^{0} 15'. But the above fact will result in a cut of 3^{0} 20', and VM will be lifted 240 years from the intended 123 B. C., towards his true place, 505 A.D.

Now we may pass on to consider (ii), Viz., VT's statement that in April 1909 A.D. there is an *Ayanāṃśa* of 28^{0} 15', taking it to be zero at VM's time, when according to VT the Vernal Equinox was + 3^{0} 20' from the zero point. VT makes up the 28^{0} 15' necessary for him by

piecing together four different quantities: (a) the distance between the Vernal Equinox and the zero point, both referring to VM's time, equal to 3 20'; (b) the late L. D. Swamikannu Pillai's (LDS) calculation of the *Ayanāṃśa* in 1909 to be 22^0 25' which is the equivalent in degrees of the time from the Sun at the Vernal Equinox of 1909 to its entering the Sign *Meṣa* in the same year according to *Sūryasiddhānta*; (c) what VT calls a *Bīja* (i. e. correction) of 2.18 days, equivalent to 2^0 9'; and (d) an error of observation equal to 16'. Of these four quantities, we have already seen that VT cannot have (a), by the fact that Summer Solstice was at 3/4 *Punarvasu* and not at the end of *Punarvasu* in VM's time. So 3^0 20' is cut off from the 28^0 15'. We shall not discuss (d), for we can readily concede his modest demand of 16' as error of observation, except to point out what mischief even this can do. That leaves us (b) and (c) to deal with.

We shall take (b) first. VT uses the *Ayanāṃśa* 22^0 25' calculated by LDS in a manner not intended by him. To understand how it is so, it is necessary to make clear the principle involved in the calculation.[37] LDS found from the *Nautical Almanac* that at 0.2143 day on the 21st March, 1909, the True Sun was at the Vernal Equinox. He found that according to the *Sūrya Siddhānta* (modern, not the *Saura* of *PS*), the True Sun reached the *First Point of Meṣa* at 0.9492 day on 12th April 1909. From the difference between the two moments equal to 22.7349 days, using the rate of motion of the sun at that interval, he calculated the *Ayanāṃśa* to be 22^0 25'. Suppose LDS had used the time of the True Sun at *Meṣa* (*Meṣa Saṅkramaṇa* as it is called) of some other *Siddhānta* or some other Almanac like the *Dṛk* Almanac or *Vākya* Almanac, he would have got different *Ayanāṃśa*s (for it is a well-known fact that Almanacs vary in their times of *Saṅkramaṇa*). Which *Ayaṇāṃśa* are we to adopt? Which is the 'correct' *Ayanāṃśa*? By 'correct' *Ayanāṃśa* is meant the total precession in degrees, of the Vernal Equinox, from a specific point on the Ecliptic which we call the Zero Point, during the interval between 1909 and the time when we take the Vernal Equinox to conincide with the Zero Point, in our case the time of VM. According to this criterion none of the present day Almanacs gives the 'correct' *Ayanāṃśa*. The following is the reason. If

the length of the year adopted by an almanac is the correct Siderial year, viz., 365 days, 15 *nāḍis*, 22.9 *vināḍis*, so that at the end of every year the Sun returns to the specified Zero point, then this way of finding the *Ayanāṃśa* will yield the 'correct' *Ayanāṃśa*. But the old system Indian Almanacs use instead of the above correct Siderial year, the Siderial year of the *Āryabhaṭīya* (365-15-31-15, adopted by the *Vākya* Almanacs), or of the new *Sūryasiddhānta* (365-15-31-31, adopted generally by LDS in his Ephemeris) and the like, which though called Siderial, are very nearly Anomalistic, being about 8.5 or 8.6 *vināḍis* longer than the correct Siderial year. As a result, the *First Point of Meṣa* moves forward leaving the *Zero Point* behind at the rate of 8.5' per annum. So if we adopt LDS's method of using the time of the True Sun at the *First Point of Meṣa* according to a particular Almanac to get the *Ayanāṃśa*, we must deduct from the gross *Ayanāṃśa* got, the accumulated interval between the *Zero Point* and the *First Point of Meṣa* of that Almanac, to get the correct *Ayanāṃśa*. (This accumulated interval may be called the 'Procession'of the *First Point of Meṣa* for that Almanac). It is this correct *Ayanāṃśa* that should be divided by the correct rate of precession of 50'. 2585 etc. to get the year when the Vernal Exquinox was at the Zero Point. If on the other hand we use the gross *Ayanāṃśa* got by LDS's method, we should divide it by the gross rate of precession, (which is the correct rate of precession 'plus'about 8.5"), to get the year; for the gross *Ayanāṃśa* increases not by the correct rate of precession but by the gross rate of precession, viz. 50".2595 etc. etc. increased by about 8.5". This is the reason why most Indian systems give nearly 1' as the rate of precession. The reader will find my statement corroborated by sections 64 and 277 of LDS's Indian Chronology (Madras, 1911).

This is the reason why LDS divided his gross *Ayanāṃśa* by 58".78 and got 536 A.D. for VM as a first approximation.[37a] The gross rate of precession 58".78 is got from the rate of procession (viz.8".52) plus the rate of correct precession, 50".26 for it is at this combined rate of 58".78 that the Vernal Equinox recedes with reference to the *First Point of Meṣa*, per annum. From this we see it is wrong to use for this purpose the actual rate of precession given by the system, if any,

as for *eg.* 54" per annum in the case of the new *Sūryasiddhānta* or 1' per annum in the case of certain other *siddhāntas*, and so on; for these *siddhāntas* have found the rates of precession by actual observation of the Sun at the Vernal Equinox, and there is likely to be an error in the observation. According to the error the rates may vary. The nearer their rates are to 58".78, the better are their observations.

It is incumbant on our part, in the present context, to answer certain remarks made by VT on the above procedure of LDS. VT remarks:[38] There are the following drawbacks in the whole argument (of LDS):

(a) It was considered that *Dakṣiṇāyana* began when the sun reached the beginning of *Karkaṭaka* instead of the end of *Punarvasu*.

(b) The fact that the modern tropical year goes on decreasing at the rate of 0.53 seconds per century was not taken into consideration.

(c) At least at the time of Varāhamihira, the Indian Siderial year - so designated at present - was really a tropical year and the value for the precession of the equinoxes must be taken as 50. 2585 - n X.000225 and not as 54" 7505 as assumed by Swamikannu Pillai.

Of these (a) has already been answered. As for (b), in the 14 centuries considered by LDS the time neglected by him is about 56 seconds, equivalent to 2" of the Sun's motion. Is this not negligible in the context? As for (c) this is against the internal evidence of the *PS*. Excepting the *Vāsiṣṭha* and the *Romaka*, all the other *Siddhāntas* in it give Siderial years. The *Pauliśa* gives 365 days, 15 *nāḍikās*, and 30 *viṇāḍikās*, the *Saura*, 365-15-31-30, and the *Paitāmaha* 366 days. By what stretch of imagination can these be called Tropical years, these years that are so far greater than the correct Siderial year that they border on the Anomalistic? As for LDS not taking 50" .2585 for division, we have answered it by saying that this would be proper only if the correct Siderial year, 365-15-22.9, had been used throughout the period of which we are considering the *Ayanāṃśa*. Secondly, where has LDS assumed a rate of precession of 54".7505, and in which context?

It should not be thought that because the modern *Dṛk* Almanacs use the correct Siderial year equal to 365-15-22.9, the time of the True Sun at their *First Point of Meṣa* will give the correct *Ayanāṃśa*. These Almanacs were started recently and they arbitrarily fixed for themselves such *Ayanāṃśa*s as would keep their *Saṅkramaṇa*s within reasonable distance from those of the old Almanacs. The very fact that the *Saṅkramaṇa*s vary only within a matter of *nāḍi*s, shows this, for considering the difference between the correct Siderial year and the so-called Siderial years of our *Siddhānta*s, even within a period of 420 years there will be a difference of one day, and for the period we are considering, viz. 1400 years or more, there should be a difference of more than three days, the *Dṛk Saṅkramaṇa*s occurring earlier. To avoid the hue and cry that would be raised if the *Saṅkramaṇa*s in their Almanacs are found to occur thus more than three days earlier, the *Dṛk* Almanac makers fixed for themselves *Ayanāṃśa*s that would keep their *Saṅkramaṇa*s near enough to those of the old system Almanacs.[39] The *Caitra* or the *Dhaniṣṭha pakṣa* has come in handy for them to fix their *Ayanāṃśa* in this manner, but these *pakṣa*s are contradictory to all schools of traditional astronomy which have adopted the *Raivata Pakṣa* alone.[40]

To continue the main argument; as, in the manner already stated, the number of years got to be deducted from 1909 to find the Zero point should be the same, whether we divide the gross *Ayanāṃśa* by the gross rate of precession, or the correct *Ayanāṃśa* by the correct rate of precession, and as the rates as in the ratio 7:6 approximately, the gross *Ayanāṃśa* found by LDS (by using the time of *Saṅkramaṇa* of the new *Sūryasiddhānta*) should be reduced by one seventh of itself to get the equivalent correct *Ayanāṃśa*, which we find to be 19^0 12'. So VT can have only 19^0 12' and not 22^0 23' by (b).

Now we pass on to (c). What VT says amounts to this: *Kali* began at midnight 17/18, February 3102 B. C. But most Ephimerides give 0.579 days after sunrise on 15th February as the Epoch of *Kaliyuga*. So there is a difference of 2.18 (?2.17) days which must be a *Bīja* correction. So we must add 2.18 days to the time of the *True Sun*

reaching the *First Point of Meṣa* in (b), viz. 0.9492 on 12th April. Thus the interval in days is increased by 2.18 days; which means 2° 9' more in *Ayanāṃśa* which will make up the 28° 15' required. Now what VT thinks to be a *Bīja* is really the interval between the times of the True and the *Mean Suns* reaching the *First Point of Meṣa*. According to Indian Astronomy the Sun's Equation of the Centre is about 2° 9' and at the time of *Meṣasaṅkramaṇa*. So the *True Sun* is in advance of the *Mean Sun* by 2°9' and reaches the *First Point of Meṣa* earlier by about 2.18 days. As the Apogee of the Sun has an extremely slow motion according to Hindu astronomy, the 2.18 days practically continue through the ages to be the same. In (b) LDS took for calculation the interval between the *True Sun* at the Vernal Equinox and the *True Sun* at the *First Point of Meṣa,* which is quite proper. If he had taken the interval between the times of the *Mean Sun* at Vernal Equinox and the *True Sun* at the First Point, then indeed we shall be justified in adding 2.18 days; for then the interval first got would have been less by 2.18 days, on account of the *Mean Sun* reaching the Vernal Equinox later 2.18 days than the *True Sun*. If we add 2.18 days, as we ought to now, we get the same interval of 22.735 days. Thus VT cannot have (c).

The error of observation, (d), is possible and may be allowed if required; but it must be remembered that is it arbitrary, indefinite and may be plus or minus. VT has taken (d) as error of observation, not from *a priori considerations*, but a *posteriori*, because this alone will give him, when added to the other quanitities and divided by 50". 2585 etc., 2031 years to be deducted from 1909 and get 123 B. C. So the reader is warned against getting predisposed in favour of 123 B. C., simply because 1909 A.D. minus 2031 is exactly equal to 123 B. C., for this particular amount of error of observation has been arbitrarily presumed to get this very result.

In conclusion, we find that in VT's *Ayanāṃśa* of 28° 15' (a) is cut off, (c) is cut off, (d) may be ignored, and (b) is reduced to about 19° 12'. If we divide this by the correct rate of precession, 50".2585 etc., we get 534 A.D. as VM's time. It may be noted how far away this is from 123 B. C., and how near it is to 505 A.D.

The *Ayanāṃśa* argument of Prof. Rai (*JPUHS* I. 124-27) is the same as VT's (a) and (b), with the difference that he takes(b) for 1931 instead of 1909. This amounts to 26° 3' 40" according to him, and committing the same mistake as VT of dividing this *Gross Ayanāṃśa* by the *actual rate of precession*, he says VM lived 1866 years before 1931, i.e., in 65 A.D. Since this does not take time to the desired 123 B. C.. Prof. Rai thinks that this discrepancy may be overcome by assuming an appropriate error of observation, which in this case has to be as large as 2 degree or so!

With showing that 427 *Śaka* of VM is 505 A.D. and that the *Ayanāṃśa* argument is fallacious, the main object of this paper is over. It is unnecessary to discuss the *Śloka*s from *Jyotirvidābharaṇa* quoted by these scholars enumerating the nine gems of Vikramāditya's court (*dhanvantari-kṣapaṇaka* etc.) and the year given therein; for in the light of the foregoing discussion these must be taken as part of a romance, or an attempt at imposture by the author of the work.[40a] Nobody will take seriously this *śloka* jumbling men of different ages together, as no one will take seriously the other romance, the *Bhojaprabandha*, for matters of history.

The Date of Bhaṭṭotpala

Both Rai and VT seek additional evidence for VM's earlier date by making his commentator Bhaṭṭotpala himself earlier than 505 A.D.[41] We shall examine this now. Bhaṭṭotpala says at the end of his commentary on VM's *Bṛhajjātaka* that he finished writing it in *Śaka* 888 (elapsed) on *Caitra Śukla Pañcamī*, which was a Thursday:

> *caitramāsasya pañcamyām sitāyām guruvāsare* I
> *vasvaṣṭāṣṭamite śāke kṛteyam vivṛtir mayā* II

Here VT says that 'the weekday does not come out correctly if we take either the *Śālivāhana Śaka* or the *Vikrama Śaka*. So the *Śaka* mentioned by Bhaṭṭotpala refers only to the *Śaka* with 550 B. C. as epoch"[42]. This means that if Bhaṭṭotpala's *Śaka* is taken as given in the *Śaka* of 550 B. C., the weekday agrees; and so the date referred

to is 888 years after 550 B. C., i.e., 339 A.D.,(but in his *'Āndhra Śaka'* he gives 340 A.D., Cf. fn. 11 above) and so VM must be earlier still. But we have made the calculations and find that it is 339 A.D.that does not give the agreement; in that year the *Caitra Pañcamī* falls on Friday, ending at about 35 *nāḍis*. In his *Popular Astronomy*, pp. 136-37, VT has changed the date of Bhaṭṭotpala to 338 A.D., in accordance with his changing the *Śaka* Epoch to 551 B. C. Strangely enough, here too VT asserts that he finds agreement with the weekday, viz. Thursday.[42a] My calculation here gives Sunday, i. e. three days, off, on this date. On the other hand there is perfect agreement with *Śālivāhana Śaka* 888 (corresponding to 966 A.D.) if *Caitra* is in the *Pūrṇimānta* reckoning which was prevalent in Bhaṭṭotpala's time.[43]

And there is also positive evidence to show that Bhaṭṭotpala has meant only the *Śālivāhana Śaka*. He has commented on the *Khaṇḍakhādyaka* of Brahmagupta, who says that it is a representation of the (*Ārdharātrika*) system of Āryabhaṭa.[44] This means that Brahmagupta is later than Āryabhaṭa (3600 *Kali*, corresponding to 499 A.D.) and that Bhaṭṭotpala must be later still. It is not possible to drag down, as VT and others do, both Āryabhaṭa and Brahmagupta together into the earlier centuries, for the following reasons: The date of Āryabhaṭa is definitely 3600 *Kali*, as already shown. Brahmagupta gives 587 *Śakakāla* as the epoch of his *Khaṇḍakhādyaka* (I.3). Brahmagupta elsewhere states that 3179 is to be added to the *Śaka* year to get the corresponding *Kali* year (*Cf. Brahmasphuṭasiddhānta*, I.26). Āmarāja commenting on the above verse of *Khaṇḍakhādyaka* (I.3) gives the *Kali* year corresponding to the epoch of the work (*Śaka* 587) to be 3766 by adding 3179 to 587; and also calculates and verifies the *Kṣepas* and the weekday of the epoch taking the *Kali* year 3766, which is A.D. 665,[45] which therefore must be the time of Brahmagupta. Further Brahmagupta is linked to Bhāskara II (who VT at least admits wrote his *Siddhāntaśiromaṇi* in 1150 A.D.) by an observed *Ayanāṃśa* of about 11°. He also says that in Brahmagupta's time the *Ayanāṃśa* was so little that it was "unobservable even to that expert astronomer".[46] So Brahmagupta cannot be dragged too far away from Bhāskara, and

this condition will be fulfilled only if his epoch is in the *Śālivāhana Śaka*. And so his commentator, Utpala's date, *Śaka* 888, has also to be in the *Śālivāhana Śaka*.

Prof. Rai advances another argument,[47] which is his own and not given by anybody else. It is this: *BS*, VIII. 20-21, gives a rule from which, by using the *Śaka* year, the corresponding Jovian year in the 60 year cycle *Prabhava* etc., can be got. He works it out for 1932 using the *Śaka* starting from 550 B. C., and gets 52 years gone in the *Prabhava* series. Using the years gone in the *Śālivāhana Śaka* of 78 A.D., he gets the 18th year in the series, viz. *Tāraṇa*. He finds this *Tāraṇa* given in North Indian Almanacs. But he says this proves nothing beyond showing that the North Indian almanac-makers have adopted the *Śālivāhana Śaka* for this rule. But the point at issue is which is the correct *Śaka* for this rule. But the point at issue is which is the correct *Śaka* to take. This can be found by working out the year from the *Kali* years gone till 1932, and seeing which of the two (52 or 18) it agrees with. Prof. Rai works out the Jovian years gone from the beginning of *Kali*, using the elements of the *Sūrya Siddhānta*,[48] and dividing the result by 60 gets the remainder 52. Lo! This is the same as the remainder got by using the *Śaka* of 550 B. C. So, that is the *Śaka* intended by VM in his *Bṛhat Saṃhitā*, he says: The argument seems to be perfect.

But this is the fallacy in it: If the Jovian year is to be worked out a priori using the *Kali* years gone, the years should be counted from *Vijaya* and not from *Prabhava*. This condition is specified in the very *Sūrya Siddhānta* whose elements Prof. Rai uses for computation and this has been missed by him.[49] Now counting 52 from *Vijaya*, we get only the 18th year of the *Prabhava* series, viz. *Tāraṇa*, and this agrees with *Śaka* of 78 A.D. and not the *Śaka* of 550 B. C. Thus Prof. Rai's argument fails. If anything, it is only a proof for taking VM's *Śakakāla* to be the *Śālivāhana Śaka*, and discarding the *Śaka* of 550 B. C.

Prof. Rai seeks further support to his theory by stating (ib., p. 71) that, "Albiruni writing in 1930 A.D. not only talks of Bhāskarācārya, but also mentions his book *Karanakutūhala*, that the date of composition of *Karaṇākutūhala* given in the work itself, viz. *Śaka* 1105, if taken in

the *Śālivāhana Śaka* would be 1183 A.D., *i.e.*, 150 years after Albiruni, which is patently impossible, that "Weber in his book on Sanskrit Literature (p. 262) notices this anomaly, but is unable to offer any explanation" (Weber, *History of Indian Literature*, English Translation, London, 1914), and the "if we take this *Śaka* commencing from 550 B. C., the riddle is solved", for this would take Bhāskara to the 6th cent. A.D., long prior to Albiruni.

The answer to Prof. Rai is given by Bhāskara himself who indicates that he uses only the *Śālivāhana Śaka* for he says that 3179 is to be added to the *Śaka* year to get the *Kali* years gone (*Cf. Siddha. Śiromaṇi, Gaṇita, Madhyama, Kālamāna*, 28). Moreover Albiruni's words in the context do not warrant the name Bhāskara at all, nor does he mention anywhere a work '*Karaṇa-kutūhala*' (the work named being a *Karaṇa-sāra*). It has also to be added that Prof. Rai is not speaking the facts when he says that Weber "is unable to offer any explanation". As a matter of fact, in contradiction to what Prof. Rai says, Weber offers on the very page that Rai refers to (page 262) several explanations: Weber says that "we have scarcely any alternative save to separate Albiruni's 'Bashkar' son of 'Mahdeb', and the author of '*Karaṇasāra*' from the Bhāskara, son of Mahādeva, and author of *Karaṇakutūhala*. (Note that none of the three names, neither that of the author, nor of his father, which is really Maheśvara and which Weber himself draws attention to in a footnote, not of the work, tallies). Weber again suggests that his translation of the Arabic Words of Albiruni might be wrong, for "Albiruni usually represents the Indian bh by b-h, and for the most part faithfully preserves the length of the vowels, neither of these is here done in the case of Bhāskar, where, moreover, the *s* is changed into *sh*", and adds in a footnote that in the passage under discussion "there lurks not a Bhāskara at all, but perhaps a Pushkara".[50] Even if the passage refers to a Bhāskara, Weber suggests that "we may have to think of that elder Bhāskara, who was at the head of the commentators of Āryabhaṭa, and is repeatedly cited by Pṛthūdakasvāmin, who was himself anterior to the author of the *Śiromaṇi*". It is in the face of these facts that Prof. Rai coolly asserts that Weber "is unable to offer any explanation"!

We may add here that the epoch of *Karaṇasāra*, which is mistaken for *Karaṇakutūhala*, is given by Albiruni as *Śaka* 821 (A.D. 899) (*Alberuni's India*, Sachau, I.392), and obviously Prof. Rai's Bhāskara of the 6th cent. Cannot write a work 300 years later! So Prof. Rai's argument only goes against his own theory.

Thus nothing can shake the evidence showing that the *Śaka* mentioned by VM is the *Śālivāhana Śaka* and that the date *Śaka* 427 given by him in his *PS* is 505 A.D. Incidentally it has also been shown that the *Śaka* era used by Brahmagupta, Bhaṭṭotpala and Bhāskara II is the *Śālivāhana Śaka* of 78 A.D.

We propose to show in a subsequent article the untenability of certain other claims of these scholars referred to in the Introduction and that everywhere when the word *Śaka* occurs as the name of an era, it is only the *Śālivāhana Śaka* that is meant, and therefore or otherwise there is no case for postulating a Cyrus or *Āndhra* Era of 550 B.C..

NOTES AND REFERENCES :

1. *Cf.* his *Age of Śaṅkara* (Madras, 1918), Pt. I, D, 224ff.
2. *Cf.* his article, *The Persian Emperor Cyrus, the Great, and the 'Saka Era'*, *Journal of the Punjab University Historical Society, (JPUHS)*, I (1932) 61-73, 122-36.
3. *Cf.* his plot in *Indian Chronology* (Vijayawada, 1953) 49-51; '*Indian Eras*', *Journal of the Andhra Historical Research Society, (JAHRS)* 20 (1949-50), 43 ff; 21 (1950-52) 61-73, 122-36.
4. *Cf.* his *Ayanāṃśa and Indian Chronology : The Age of Varāhamihira, Kālidāsa etc.* in *Journal Of Indian History (JIH)* 28 (1950) 103 and '*The Andhra Saka*' *JAHRS*, 22 (1952-54) 161-82.
5. In his *Popular Astronomy* (Madras, 1958), pp. 135, 136, VT has changed to 551 B. C. without assigning reasons therefore.

6. *Cf.* Summary of his paper, '*On the Origin of Saka-kala*', *Proceedings of the Indian Historical Congress*, Fifth Session, Hyderabad, 1941, p. 164, of which nothing more is known.

7. In the case of Bhāskara II alone, VT concedes that the *Śaka* Era mentioned by him is the *Śālivāhana Śaka.*

8. e.g., Brahmagupta's *Brahmasphuṭa-siddhānta*, *Madhyamādhikāra*, I. 26; Bhāskara I's *Mahābhāskarīya*, I.4, and *Laghubhāskarīya*, I.4; Śrīpati's *Siddhāntaśekhara*, I.25; Bhāskara II's *Siddhāntaśiromaṇi*, *Gaṇita*, *Madhyama.*, *Kālamāna*, 28.

9. *Cf.* VT, *Popular Astronomy*, 137; Kota Venkatachelam, *The Plot in Indian Chronology*, Appendix, p. xxx.

10. *JPUHS* I (1932) 124-27; and *JIH* 28 (1950) 103ff and *JAHRS* 22 (1952-54) 172. Following his change to 551 B. C. as the *Śaka* Epoch, in his *Popular Astronomy*, VT has changed VM to 124 B. C. from 123 B.C. But the arguments for the refutation of 123 B. C. are applicable in toto for the refutation of 124 B. C. also.

11. *JPUHS* I (1932) 73 (date given 338 A.D.), and *JIH* 28 (1950) 123 (date given 339 A.D. In his *Popular Astronomy* VT has shifted this to 338 A.D. But in his '*Andhra Saka*' VT gives this date as 340 A.D. (ib., p. 173).

12. *Somadivasādye* is the reading as emended by the late Dr. Thibaut and MM. Sudhakara Dvivedi in their edition of the *PS*. From the two manuscripts of the work available for the edition and from quotations elsewhere, four readings are known: *saumya-divasādye, bhaumya-divasādhyaḥ, bhauma-divasādhyaḥ and bhauma-divasākhyaḥ.* On the propriety or correctness of these readings see below.

13. *Khaṇḍakhādyaka*, (Tr. P. C. Sengupta. Calcutta, 1934), I. 3-5, 13, 14; II. 1-5.

14. *Cf. Bṛhatsaṃhitā*. Ed. Sudhakara Dvivedi, Benaras, 1895, Pt. I, pp. 28-30.

15. 3606 after *Kali* is not 504 A.D. as some people may think. As there is no zero year B. C. or A.D., we apparently arrive at a date one year later

than the correct date. For errors of this kind see Kota Venkatachelam, *JAHRS* 21 (1950-52) 4,7 etc.; Gulshan Rai, *JPUHS,* ib. 73, 127.

16. *PS ch. XVI.* (Thibaut and Sudhakara Dvivedi's Edn. Reprinted by Motilal Banarsi Dass, Lahore, 1930).

17. See under *PS* XVI. 9, '*davo vilipti*'.

18. *PS*. IX. 1.

19. S. B. Dikshit has arrived at the same result independently. See his article, '*The Original Sūrya-Siddhānta*', *Indian Antiquary* (IA), 19 (1890), 49, 54.

20. Dikshit, Ib., 45-54.

21. *Ib.*, 46-47.

22. *JIH* 28 (1950), 108.

23. It will be shown below that there is absolutely no weight in either of these objections.

24. If it is 124 B. C., to which VT has shifted in his *Popular Astronomy*, the weekday is Thursday, and this is an additional argument against his date.

25. *Ib. IA.* 19 (1890) 45 ff.

26. VT has mistaken (*JIH* 28, p. 108; *JAHRS* 22, p. 172) Yavanapura for Romakapura, and giving it a longitude of 90^0 west of Ujjain implies a *deśāntara* of 15 *nāḍi*s instead of 7 *nāḍi*s 20- *vināḍi*s which is specifically given as the *deśāntara* for it, in *PS* III. 13:

    Yavanāntarajā nāḍyaḥ sapta avantyām tribhāga-saṃyuktaḥ /

    For an explicit mention see *PS* XV. 25:

    anyad romaka-viṣayād deśāntaram anyad eva yavanapurāt /

    Yavanapura would correspond to Alexandria as calculated from the *deśāntara*.

27. It is only dissatisfaction and nothing more, and it may be noted that Dikshit himself gives reasons for the adoption of 505 A.D. (Ib., p. 46).

28. It may be asked why only the *Mean Caitra* and the *Mean Solar* year are taken into consideration in this explanation. It is because the word *Caitra* is given in the context of the *Ahargaṇa* rule, whose constants, multipliers and divisors depend upon the *Mean Sun* and *Moon*. If we use the *True month and Tithi* in the computation, it is because we have no othergo and that is why there has to be the check by the weekday of the Epoch.

29. The rule giving this is:

    ravisaṅkramaṇād ūrdhvam yo yo māsaḥ prapūryate cāndraḥ I
    caitrādiḥ sa jñeyaḥ pūrtidvitve 'dhimāso 'ntyaḥ II

30. Dikshit, Ib., p. 51,

31. *Mahābhāskarīya*, (Ed. T. S. Kuppanna Sastri, Madras, 1957), VII. 21-35. See also the Editor's Introduction to this edition, pp.xliv-vi.

32. There is a suggestion by some to emend *ṣaṣṭiḥ* into *ṣaḍbhiḥ* and take Āryabhaṭa to 360 *Kali* (e.g,, Kota Venkatachelam, *The plot in Indian Chronology*, Ap. III, p. xxi). But with *ṣaḍbhiḥ* the word ca in the verse becomes meaningless. Also manuscripts of the work give only *ṣaṣṭiḥ* and all known ancient commentaries explain the verse only with *ṣaṣṭiḥ* Cf. Bhāskara I's *Āryabhaṭīyabhāṣya; ṣaṣṭyabdānāṃ ṣaṣṭiḥ;, ṣaṣṭirabdāḥ ṣaṣṭiguṇāḥ ityarthaḥ*; Sūryadeva Yajvan's *Āryabhaṭaprakāśa: ṣaṭśatādhika-trisahasramiteṣu* (3600) *sūryābdeṣu gateṣu;* Parameśvara's *Bhaṭadīpikā : ṣaṭśatādhika-sahasratraya* (3600) (Edn. Kern. Leiden, 1874, p. 58); Gārgyakerala Nīlakaṇṭha Somayāji's *Bhāṣya... ṣaṣty-abdānām ṣaṣṭeḥ...kaler ārabhya ṣaṣṭyabdānām ṣaṣṭir gatā... idānīm prakṛtistham ayanam* (*TSS.* 110, pp. 12-13).

33. Rai, *JPUHS.* I (1932) 124-27; VT. *JIH.* 28 (1950) 104-06.

34. Ib., p. 104.

35. See for instance, *Sūryasiddhānta*, XI. 1-2:

    ekāyanagatau syātām sūryācandramasau yadā I
    tadyutau maṇḍale krāntyos tulyatve vaidhṛtābhidhaḥ II
    viparītāyanagatau candrārkau krāntiliptikāḥ I
    samā tadvad vyatīpāto bhagaṇārdhe tayor yutau II

36. For a fuller discussion, see the writer's Introduction to his edition of *Mahābhāskarīya*, Madras, 1957, pp. xxv-xxxv. Further, as VT has not brought into the argument either the *Caitra* or the *Dhaniṣṭhā Pakṣa* of the zero-point of the Ecliptic, we have avoided dragging them in and confusing the issue.

37. See LDS, *An Indian Ephemeris,* Madras, 1922, Vol. I, Pt. I, pp. 457-58: "Appendix (ii) Luni-Solar Precession as applied to Indian Astronomy-The year of Śūnya-*Ayanāṃśa*, A.D. 533, how determined".

37a. Using this date LDS gets 533 A.D. as the correct date.

38. His article, *JIH* 28 (1950) 105.

39. In 1925 the Almanac makers met in Conference at Poona and adopted an *Ayanāṃśa* of 22⁰ 40⁰ 39" for 1925 proposed by R. N. Apte, M. A., Professor of Mathematics, Rajaram College, Kolhapur, arrived at by taking the *True Sun*'s position as *Meṣa Saṅkramaṇa* in that year according to the *Sūrya Siddhānta* as the zero point. On this See C. G. Rajan, *Rāja Jyotiṣa Gaṇitam*, (Madras, 1933), Section - Conversion of Heliocentric etc., ch. VI, p. 56.

40. C. G. Rajan gives the actual *Ayanāṃśa* according to the *Raivatapakṣa* to be 18⁰ 56' 45". 7 in 1925; see Ib., p. 58.

40a. The unreliability of this work will be discussed later.

41. Rai, *JPUHS* I (1932) 73; VT, *JIH 28* (1950) 103, *JAHRS* 22 (1952-54) 173.

42. *JIH 28* (1950) 109.

42a. It is an obvious fact that for a particular *Tithi* in a particular month the weekday cannot be the same in two consecutive years.

43. In certain editions of Bhaṭṭotpala's commentary on the *Bṛhajjātaka* we find instead of the *śloka* quoted above, another saying that he finished the commentary on a Thursday in *Śaka* 888 on *Phālguna kṛṣṇa dvitīyā.* This too gives agreement with the weekday only if 888 is in *Śālivāhana Śaka*. If in the *Śaka* starting from 551 or 550 B. C. alleged, there is disagreement.

44. See *Khaṇḍakhādyaka*, I.1.

45. So VT's statement in his Popular Astronomy, p. 137, that only 37 A.D. which date he gives for Brahmagupta, would agree with the weekday and not any other date, is wrong.

46. *Cf.* his *Vāsanā-bhāṣya* on his *Siddhāntaśiromaṇi*, under *Golādhyāya*, *Golabandhādhikāra*, 17-19.

47. *JPUHS.* I (1932) 123-24.

48. The *Sūrya Siddhānta*, which Prof. Rai uses, wants actually the years from 'Creation'(i.e. a point 17,064,000 years from the beginning of the *Kalpa*) to be used for this. But as a whole number of 60 year cycles have gone at the beginning of *Kali*, no harm will ensue if the *Kali* year is used as he does.

49. *Cf. dvādaśaghnā guror yātā bhagaṇā vartamānakaiḥ* I
Rāśibhiḥ sahitāḥ, śuddhāḥ ṣaṣṭyā syur 'Vijayādayaḥ' II I. 55II

50. Weber's doubts about the translation of the Arabic passage are only too well-founded, for we find Sachasu translating the passage as: "Further there is an astronomical handbook... by Vitteśvara the son of Bhadatta (? Mihdatta) of the city of Nāgarapura, called *Karaṇasāra*", *Cf. Alberuni's India*, E. C. Sachau, London, 1910, Vol. I, p. 156.

Now, it is to be noted that no astronomical text spells the name as 'Āryabhaṭṭa'. The author himself mentions his name at three places only as 'Āryabhaṭa', towards the beginning and ending verses of his work *Āryabhaṭīya.* (Ref. article *Āryabhaṭa : His name, Time and Provance*).

THE UNTENABILITY OF THE POSTULATED *ŚAKA* OF 550 B.C.*

Introduction

It has been shown in the preceding study that the *Śaka* Era used or alluded to by astronomers like Varāhamihira (VM), Brahmagupta, Bhaṭṭotpala, Śrīpati, Bhāskaras I and II etc. is the era starting from 78 A.D., later known as the *Śālivāhana Śaka*, and not the era of 550 B.C. postulated by the late T.S. Narayana Sastri (TSN) or Prof. V. Thiruvenkatacharya (VT) and called by them the Cyrus Era or the *Āndhra* Era respectively. Incidentally we have shown to be untenable their statements that Āryabhaṭa belonged to 2742 B.C., VM to 123 B.C., Brahmagupta to 26 A.D., Bhaṭṭotpala to 339 A.D. and Bhāskara II to 522 A.D., and thereby we have proved that VM belongs to 505 A.D. and Bhaṭṭotpala to 966 A.D. and indicated that the real date of Āryabhaṭa is 499 A.D. and of Brahmagupta 654 A.D.

In the same way it can be shown that wherever other astronomers or writers like Kalhaṇa and Albiruni mentions a *Śaka* Era, it is this *Śaka* of 78 A.D. they mean. The tradition of almanac makers also supports this, for they all give in their almanacs only this *Śaka* Era and not the alleged other one. In inscriptions and documents also, in short in every case where a date in *Śaka* Era is given, it is this *Śaka* alone, though this is disputed by TSN and (till recently) by Sri Kota Venkatachelam (KV) in the case of the Aihole Inscription (to which we shall revert later).[1]

II. *Bṛhatsaṃhitā*. XIII. 3 Considered

We shall now take up for discussion *Bṛhatsaṃhitā* (*BS.*) XIII. 3 of VM, referred to by us earlier (ante pp. 345-46) which TSN and others consider as their stronghold, and which we left over for detailed consideration later:

**Journal of Indian History,* Vol. XXXVII, Trivandrum, 1959 and in continuation of the previous article.

āsan maghāsu munayaḥ śāsati pṛthvīm yudhiṣṭhire nṛpatau /
ṣaḍ-dvika-pañca-dvi-yutaḥ śakakālas tasya rājñaś ca //

This stanza occurs in the context of the *Saptarṣi-cāra* or the Motion of the Seven Sages, (i.e., the group of stars Ursa Major or the Great Bear), among the twenty-seven asterisms, given for use in astrological prediction. To find the position of the group at any time, three things are necessary: (i) its position at a given time; (ii) the time elapsed from the given time to the time for which the position is required, and (iii) its rate of motion. The above stanza gives (i) and (ii), viz. that at the time of Yudhiṣṭhira's rule the Sages were at the asterismal segment *Maghā,* and the time elapsed from this time to any year in the *Śaka* Era is the number of the year in the *Śaka* Era plus 2526. (Requirement ciii) is given in the next stanza, XIII. 4, as one asterismal segment for 100 years). Now TSN and KV argue thus: (a) This stanza is a quotation from Vṛddha Garga (VG), and so VG knows a *Śaka* Era which he mentions here. It is accepted by all that VG lived long prior to 78 A.D., the starting point of the *Śālivāhana Śaka*. So this *Śaka* must be an earlier *Śaka*, viz. that of 550 B.C. postulated by them. (b) The first half of this stanza says that the Sages were in *Maghā* in Yudhiṣṭhira's time. The *Purāṇas* and VG etc. say that at the junction of *Dvāpara* and *Kali yugas*, the Sages were at *Maghā* and Yudhiṣṭhira was ruling. Twenty-five years after the advent of *Kali* the Sages moved to the next asterism from Maghā and in that year Yudhiṣṭhira left this world for heaven. The second half of the stanza states that the *Śakakāla* mentioned therein started 2526 years after *Yudhiṣṭhirakāla*. If we take *Yudhiṣṭhirakāla* to have started from the time he went to heaven i.e. after 25 *Kali* equivalent to 3076 B.C., this *Śaka* must have started 2526 years after this, i.e. from 550 B.C., and is evidently quite different form the *Śaka* starting from 78 A.D.

It is in the light of this conclusion, and in support of it, that TSN etc. say (as we have discussed already) that the *Śakakāla* mentioned by VM in other places in his works, and also by other astronomers like Brahmagupta, is this *Śaka* of 550 B.C. But we have

proved conclusively in the previous study that in those places it is the *Śaka* of 78 A.D. that is referred to.[2] Therefore the conclusion here arrived at by TSN etc. must stand on its own legs. We shall proceed to examine this now. Even at the outset we can say that it is extremely unlikely that VM means here alone a *Śaka* different from what he means by the same word elsewhere in his works; and therefore he must mean the *Śaka* of 78 A.D. here also. All the same we shall examine their arguments.

(a) **The Alleged Quotation of Vṛddha Garga**

Their reasoning (a) is based on the assumption that the stanza is a quotation from VG, which it is not. The actual words of VG are quoted by the commentator Bhaṭṭotpala in his commentay on this stanza: *cf. tathā ca vṛddha-gargaḥ : Kali-dvāparayoḥ sandhau sthitās te pitṛdaivatam* (At the junction of *Kali* and *Dvāpara*, they - the Sages - were at *Maghā*). It is to be noted that this would be redundant if the stanza in question also were VG's, both giving the same idea, viz. the situation of the Sages. It may also be noted that this is in a different metre. What VM means by his statement in the introductory stanza, *kathayiṣye vṛddha-garga-matāt* (*BS*. XIII. 2) is only that he is giving the astrological predictions due to the motion of the Sages as based on the work of VG, as indicated by the word *matāt* (opinion) used here. Also in all the other *cāra*s given in all the other chapters of *BS*, like *Ādityacāra, Candracāra, Rāhucāra* etc., what VM means by *cāra* is the prediction based upon the motion and not the actual motion, and so must it be here also, (the actual motions being given in a *Gaṇita* work like the *Pañcasiddhāntikā*). If in the case of the Sages the motion also is given, it is because it is simple, has not been given elsewhere, and is necessary for the main purpose, viz. the predictions according to the motion. Thus it is the prediction that VM says he gives according to VG. So this stanza which serves to find the position of the Sages need not necessarily be, and as we have shown, is not, VG's.[3] This being the case, it cannot be argued that Garga who came long prior to 78 A.D. knows a *Śakakāla* and therefore this *Śakakāla* must be the earlier postulated one of 550 B.C.

(b) The Time of Yudhiṣṭhira

We now pass on to consider (b) the second and more important reasoning of TSN etc., viz, that VM in this verse refers to Yudhiṣṭhira who lived at the beginning of *Kali* and rose to heaven 25 years after *Kali* set in (i.e. in 3076 B.C.) and so the *Śaka* Era beginning 2526 years after that must be the postulated *Śaka* of 550 B.C. But we answer, there is nothing in this verse to show that in VM's opinion Yudhiṣṭhira lived at the beginning of *Kali*. On the other hand it can be shown that VM might have meant a time about 650 years after *Kali* or even that he did mean this later period for the time of Yudhiṣṭhira, and therefore the *Śaka* era following 2526 years after, cannot be the postulated *Śaka* of 550 B.C., but can only be the well-known *Śaka* of 78 A.D. It is a fact well-known to scholars (inclusive of TSN etc.) that the junction of *Dvāpara* and *Kali* (3102 B.C.) is not the only period with which Yudhiṣṭhira is associated. This is according to one school; but there is at least one other school (e.g. that of the Jain and Buddhist writers) who take it that Yudhiṣṭhira lived about 500 years later. They use a *Yudhiṣṭhira* Era which began in 468 *Kali* (corresponding to 2634 B.C.).[4] Even of the first school mentioned, not all associate the same event of Yudhiṣṭhira's life with the beginning of *Kali*, 3102 B.C. There are four sub-schools here (Fleet says three, but mentions all four, *JRAS* (1911) 676-78, 'The *Kaliyuga* Era of B.C. 3102'). One sub-school believes that the first coronation of Yudhiṣṭhira at Indraprastha was the beginning of *Kali* and the commencement of the *Yudhiṣṭhira* Era.[5] Another makes the Bhārata war and the beginning of *Kali* synchronous.[6] A third says that *Kali* began at the death of Kṛṣṇa and his ascent to heaven.[7]

The fourth sub-school says that Yudhiṣṭhira's abdication and starting on the *Mahāprasthāna* was at the beginning of *Kali*.[8] The reason why there are so many views must be explained by the fact that the traditional idea of the ages like *Kṛta, Tretā, Dvāpara* and *Kali* with their specific characteristics, was earlier than the integration of the beginning of the traditional *Kali* with that of the astronomical *Kali* answering to 3102 B.C., computed later by astronomers like Āryabhaṭa so as to form a convenient point of reference for the Mean Planets. Thus the *Kali* Era, said to begin with 3102 B.C., is an extrapolated era,

and in examining any date mentioned in this *Kali* Era, this fact should be borne in mind.

Now in this multiplicity of schools on this point, which is a fact accepted by all, resulting from the integration of the traditional *Kali* with the astronomical *Kali*, there is the possibility of VM's statement representing one other school or at least a variant of the Jain school, differing as it does, from it only by about a century. Kalhaṇa, the Kashmirian chronicler of the 12th cent. A.D. is one of those that subscribe to this school; for not only does he quote in his *Rājataraṅgiṇī* this verse of VM, but also expresses his own concurrence with it in so many words:

> *bhāratam dvāparānte 'bhūd vārtayeti vimohitāḥ* /
> *kecid evam mṛṣā teṣām kālasaṅkhyām pracakrire* // I.49 //
> *śatesu ṣaṭsu sārdheṣu tryadhikeṣu ca bhūtale* /
> *kaler gateṣu varṣāṇām abhūvan kuru-pāṇḍavāḥ* // I.51 //
> *ṣaḍ-dvika-pañca-dvi-yutaḥ śakakālas tasya rājñaś ca* / I.56b//

'Some people have been misled by the statement that the Bhārata (War) was at the end of Dvāpara, and have given a wrong chronology to the kings (the Pāṇḍavas, Gonanda etc.)... The Kurus and the Pāṇḍavas came when 653 years had passed in *Kali* ... The time in the *Śaka* Era plus 2526 is the time of his rule, i.e. the time in the epoch beginning from his (Yudhiṣṭhira's) rule'. It may be noted that 653 plus 2526 (the numbers here given) equal 3179, the well-known converter of *Śaka* into *Kali* and vice versa. Not only is Kalhaṇa a believer in this school, but he is also certain that VM belongs to this school, as seen by his statement '*Saṃhitākāraiḥ*' (*Rājataraṅgiṇī*, I. 55). and his quotation of VM following immediately (I. 56). Cunningham also thinks the same as seen from his statement, 'As VM places the Great War 653 years after the beginning of the *Kali* Age...' (ib. p. 11). Again, Prof. P. C. Sengupta, who in his *Ancient Indian Chronology* (Univ. of Calcutta, 1947) in seeking to determine the date of the Bhārata War astronomically (see chs. I-III) favours this school, and comes to the conclusion that: 'The date of the Bhārata Battle is thus astronomically established as the year 2449 B.C. (*Kali* 653), which is supported by

the Vṛddha Garga tradition recorded by Varāhamihira.' (see p. 19). Now it must be noted that the mere possibility of VM following this school is sufficient for our purpose, as we have stated above.

Nor can the objection be raised that VG and the *Purāṇas* associate the Sages with *Maghā* at the beginning of *Kali*, and that in this verse too, as the Sages are declared to be at *Maghā* in Yudhiṣṭhira's reign, the time here should be taken as the beginning of *Kali*, and so the time given for Yudhiṣṭhira's rule must be the beginning of *Kali*, and not 653 *Kali*. For, the beginning of *Kali* is not associated with *Maghā* alone. The *Matsya Purāṇa* says (ch. 271, sl. 41) that, according to the Śrutarṣis the Sages were at *Kṛttikā* at the beginning of *Kali*, and TSN and KV, are aware of it (TSN quotes it and explains it, see The Age of Śaṅkara, Madras, 1916ff.) App. pp. 166-67; see also KV. *Plot in Indian Chronology*, 34-36). They themselves say that in VM's opinion also the sages were at *Kṛttikā* at the beginning of *Kali* (TSN, ib., p. 171; KV, ib., p. 36, and 'Indian Eras', *JAHRS* XX. 77).[9] According to Āryabhaṭa II and Parāśara too (for details, see below), the Sages were at *Kṛttikā* at the beginning of *Kali*. They were at Śravaṇa according to Śākalya and Munīśvara, and at *Rohiṇī* according to Lalla (for details, see below). So the objection raised above does not stand. Now according to Āryabhaṭa II and Parāśara, who give *Kṛttikā*, it is easily seen that the Sages will be in *Maghā* in the 7th cent. *Kali*, for *Maghā* is the seventh asterism for *Kṛttikā* and the motion is about one century per asterism. Thus there can be no objection to the Sages being in *Maghā* in the 7th cent. *Kali*. It is only if the motion of the Sages is taken to be retrograde (as TSN and certain others think) according to Āryabhaṭa II, Parāśara and VM, that the Sages cannot be in *Maghā* in the 7th cent. *Kali*, but would be far away from it. But it is not retrograde according to Āryabhaṭa II, Parāśara and VM, as also according to other astronomers who give rules for the motion, which we shall show.

III (a). The Motion of Sages-Direct, not Retrograde

This requires a knowledge of the motion of the Seven Sages[10] which we shall give in some detail because there is a lot of misconception among scholars (including TSN, KV and VT) about this,

which in turn vitiates the results of their researches. It was believed by the authors of the ancient *Jyotiṣa Saṃhitā*s, like VG, that the Sages had a motion of their own among the other stars, just like the planets, the rate of motion being given as 100 or nearly 100 years per asterism (13^0 20'). It may be said even at the outset that there is no such motion as claimed to exist by the authors of these *Saṃhitā*s and followed up by the *Purāṇa*s and some of the later astronomers; that the Sages are always to be associated only with the *Phalgunī*, *Hastā* and *Citrā* asterisms (see fn. 10); and that the theory of their motion is wrong, howsoever it might have originated.[11] That is why many standard astronomers and astronomical works like Āryabhaṭa I, Brahmagupta, Śrīpati, Bhāskaras I and II, the *Sūryasiddhānta*, etc., do not deal with the subject at all, as being outside the pale of real astronomy. That is also why Kamalākara is constrained to say in his *Siddhāntatattvaviveka* (Banaras, 1880-85), *Bhagrahayutyadhikāra*:

> *śākalyasamjña-muninā kathitās sabāṇāḥ*
> *saptarṣitārakabhavā dhruvakāś calāś ca //25a//*
> *yairgolatattvam vivṛtam hi taiś ca*
> *sūryādibhir naiva viśeṣa eṣaḥ /*
> *proktas svaśāstre 'sti gatir munīnām*
> *ato na yuktā divi golarītyā // 30 //*
> *adyāpi kair api narair gatir āryavaryaiḥ /*
> *dṛṣṭvā na yā 'tra kathitā kila saṃhitāsu //32a //*
> *prāyo 'tha te ca munayaḥ kila devatāṃśā*
> *dṛggocarā nahi nṛṇām iha satphalāptyai //36a //*

'Sage Śākalya has given the motion of the Sages with their positions in his time ... Sūrya and others who explain the nature of the celestial sphere in their works do not give it and therefore the theory cannot be sustained astronomically .. Even today this motion mentioned in the *Saṃhitā*s is not observed by knowing astronomers ... Therefore the seven real Sages who are the presiding deities (of these stars) are to be considered to be moving, unobserved by men, for the prediction of the fruits thereof'.

But the motion has been accepted as a fact by the common people and the authors of the *Purāṇas*, and an era called *Laukika* Era (by the people belonging to the Kashmir region) and the *Saptarṣi* Era (by the Purāṇas), has been founded upon this theory.[12] As already mentioned there are also astronomers like VM, Āryabhaṭa II (cf. his *Āryasiddhānta* or *Mahāsiddhānta, Madhyamādhyāya,* 11), Parāśara (cf. *Āryasiddhānta, Parāśaramatādhyāya*, 9), Lalla (quoted by Munīśvara in his commentary on the *Siddhānta Śiromaṇi*), Śākalya (quoted by Munīśvara, ib. and by Kamalākara in his *Siddhānta Tattvaviveka, Bhagrahayutyadhikāra*, 25 and under), and Munīśvara (see his *Siddhānta Sārvabhauma*) who have accepted the motion as real on the authority of the ancients and given rules for the motion, which necessarily must agree with their own observation, or else they would be meaningless even for them.[13] This means that whatever be the rule, if applied to the time of the author, the position of the Sages must be got as between *Maghā* and *Svātī*[14]. In giving the rules the authors all consider the motion as direct and never as retrograde as fancied by some scholars like TSN, KV, VT, etc. for which fancy there is no support anywhere.[15] Let us take the rules one by one and examine them for the facts mentioned.

VM's rule is as follows: (*BS*. XIII. 3-4). The number of years gone from the time of Yudhiṣṭhira is to be found by adding 2526 to the *Śaka* years gone at the time for which the position of the Sages is wanted. This is to be divided by 100, which gives the number of asterismal segments gone, and these are to be counted from *Maghā* to get the position. In the context there is no mention of any retrograde motion, nor is it mentioned that the number got is to be counted backwards as in the case of the *Pāta*s like *Rāhu*. In the absence of any such specific indication we do what is normally done, i.e., count the segments forward, as in the case of all other grahas like the Sun etc. Working for VM's time, i.e. 427 *Śaka*, we get the middle of *Uttara Phalgunī* as the position of the Sages, which is well within the limit for agreement with observation. If we count backwards taking the motion as retrograde, we get the middle of *Puṣya*, which is far outside the limit, and this also shows that the rule implies only forward motion, as we have already determined.

Āryabhaṭa II gives the rule in the form of cycles per *Kalpa*, even as the *Siddhāntas* do for the planets. He says there are 15,999,98 cycles in the *Kalpa* and the cycles commence 30,24,000 years from the beginning of the *Kalpa*. Here too there is no indication of retrograde motion. Calculating from the above date we find that at the beginning of the present *Kali* the Sages are at 2.38 segments (counting from *Aśvinī*), i.e. they have passed *Bharaṇī* and been in *Kṛttikā* for 38 years. It is easily seen that at 662 *Kali* the Sages will cross to *Maghā* according to this *Siddhānta*. Compare this with VM's rule that would give the crossing to *Maghā* in the 7th century *Kali* (exactly speaking 653 *Kali*; for going back 2526 years from zero *Śaka* equal to 3179 *Kali*, we arrive at this date.).[16]

We now pass on to Parāśara. His rule is the same as that of Āryabhaṭa II, with the difference that is Parāśara's case the cycles begins at the commencement of the Kalpa itself. This would give for the commencement of *Kali* the position 2.34 *Nakṣatras*, counting, of course, from *Aśvinī*, i.e. after crossing *Bharaṇī*, the Sages have been in *Kṛttikā* for 34 years, and at 666 *Kali* the Sages pass on to *Maghā*.[17] See how close this is to 662 and 653, the dates according to Āryabhaṭa II and VM, derived above.[18]

Now for Lalla's rule: As said before, the rule is quoted by Munīśvara in his commentary on the *Siddhāntaśiromaṇi*. It is this: Deduct 14 from the *Kali* years gone and divide the remainder by 100. Asterisms are got, which are to be counted from Rohiṇī.[19] Here too it is to be noted that no backward counting is enjoined, and the rule must normally mean forward counting as in all rules where nothing is said. It is to be noted that according to this rule, the Sages pass to *Rohiṇī* from *Kṛttikā* 14 years after *Kali* set in, i.e., they have been in *Kṛttikā* for 86 years before the beginning of *Kali*, (agreeing with VM within half a segment). Taking the date of Lalla to be 650 A.D.,[20] the Sages would be at *Citrā* in his time, according to this rule, which observation is quite possible, we see.

According to *Śākalya Saṃhitā*, '*Kratu*, one of the Sages enters *Śravaṇa* at the commencement of *Kali* and the Sages have direct motion

every year at the rate of 8' (which rate is equivalent to one asterism per century);' cf.

yugādau viṣṇutārāyāḥ kratur bhādye vyavasthitaḥ /
pratyabdam "prāggatis" teṣām aṣṭau liptā munīśvara //

(Quoted in Kamalākara's Com. on his own *Siddh. Tat. Viv.*, *Bhagrahayutyadhikāra*, under stanza 25).

So the rule would be to multiply the *Kali* years by 8 and divide by 800, to get the asterisms. These are to be counted forward from *Śravaṇa*. It may be noted that here eastward motion, i.e. direct motion, is specifically stated. Kamalākara, too explaining the motion as really that of the presiding sages, says in the same context that the motion is eastward i.e. direct; cf. *sā prāggatir munivarair bhagatā munīnām* (ib. 36). According to this rule, after 1100 A.D. the Sages would move to *Maghā*, and we can place this work at the earliest in c.1100 A.D.

Lastly for the rule of Munīśvara given in his *Siddhānta Sārvabhauma*. Deduct 600 from the *Kali* years. Double the remainder and divide by 15. The position of the Sages in degrees is got. This divided by 30 gives the position in the *Rāśi*s. This rule again clearly takes the motion as direct. According to Munīśvara the Sages cross to Aśvinī at 600 years *Kali* (which is equivalent to the statement of Śākalya, for according to Śākalya's rule too the Sages enter Aśvinī at 600 *Kali*). At the time of Munīśvara, according to his own rule, the Sages would have crossed from *Citrā* to *Svāti* which is just outside the limit, and which position Munīśvara should have accepted as agreeing with observation because the difference was not much. (It would have satisfied him better if some astronomer had said or if he could obtain by quibbling that the Sages were at *Śraviṣṭhā* or *Śatabhiṣak* at the commencement of *Kali*. No such thing was available, and the best he could have was Śākalya, and he had to be satisfied with that).

Thus all authorities either state or imply only direct motion, and there is no authority for retrograde motion. That is why scholars like Cunningham (as already mentioned), 'Śrīyut Śrīś Chandra Vidyārṇava, Dr. Jayaswal and many others' (in the words of Dr. Triveda,

JIH XIX, 11) have considered the motion direct. There may be some like 'the most famous astrologers of Benares who informed Col. Wilford', (*cf.* Triveda, ib. p. 10), and the author of the *Kaliyugarājavṛttānta* who believe the motion to be retrograde. But in the light of what we have said, they must be wrong (see fn. 15).

III (b) The *Purāṇa*s on the Motion of the Sages

We cannot get any indications regarding the direction of the motion of the sages from the *Purāṇa*s themselves, as they are vitiated by emendations and interpolations, made to affect the very point which we are trying to decide. Still, some scholars resort to them for support, and it is not surprising that they fail to establish anything. Dr. Triveda is one such;[21] he not only does not prove his point, but proves the contrary of what he desires to prove his point, but proves the contrary of what he desires to prove, as also the lack of clearness in his mind. For e.g.: He says: (i) "But in fact their (the Sages') motion is retrograde as is clear from the word Precession, pre = *pūrva* or east, and cession from Fr. Cedare = go" (ib., p.11). (ii) "Kamalākara Bhaṭṭa also says in his *Siddhāntatattvaviveka*, '*pratyabdam prāggatis teṣāṃ*'; that is, in every year their motion is from West to East". (ib., p.1). (iii) "C.A. Young in his *A Text Book of General Astronomy* Published in 1904 says on page 141, "The Equinox moves westward on the ecliptic, as if it advanced to meet the Sun on each annual return'. So it is certain that their motion is contrary to that of the Sun, and it is retrograde". (*ibid.*, p. 11). Let us examine his statements here. (i) If Precession is retrograde, why should the motion of the Sages be retrograde also? Are they the same phenomenon? If he means that the motion is derivable from Precession, he has not shown it, and cannot show it, because it is not so (see fn. 11 (i) above). Even if some connection be established between the two, in the period we are considering the simulated motion would be directed only opposite to Precession (see fn. 11 (i) above). He is not aware that the derivation he gives for the word 'Precession' would mean direct motion even for Precession, and not retrograde motion for 'going east' means 'direct motion'. (ii) Dr, Triveda's quotation from Kamalākara is plainly against himself, for 'from west to east' is

'direct motion', and not otherwise as Dr. Triveda thinks (iii) Young rightly says that the Equinox moves westward, i.e. it has retrograde motion. But what has that to do with the Sages? Triveda does not perceive that from here it can be understood that it is westward motion that is retrograde, and not eastward motion, as he thinks.

Under the delusion that he has proved the motion of the Sages to be retrograde, Dr. Triveda proceeds to apply this to the following statement in the *Purāṇas* in order to establish his thesis that the interval between Parīkṣita and Nanda is 1500 years (given by one reading) and not 1015 or 1050 years (given in certain other readings) (cf. Triveda, ib., pp. 1-3, 12-15). We shall briefly examine this in order to expose the mistakes in his reasoning, for if he establishes his point by using his theory of retrograde motion that might be taken by some as a point in favour of the theory of retrograde motion itself, even after all that has been said by us to establish that the motion is direct.

The Puranic statement is as follows:[21a]

mahāpadmābhiṣekāt tu yāvaj janma parīkṣitaḥ /
or
yāvat parīkṣito janma yāvan Nandābhiṣecanam /
evam varṣasahasram tu jñeyam pañcāśaduttaram (1050) //

The last foot has the variants: *śatam pañca daśottaram* (i.e. 1510) or *pañcadaśottaram* (i.e. 1015) or *pañcaśatottaram* (i.e. 1500), (*Viṣṇupurāṇa*, IV. xxiv. 104; *Bhāgavata*, XII.ii. 26; etc.). Triveda's thesis is to establish the interval to be 1500 or 1510 (according to two readings given) using the *Saptarṣi* Era given in the following Purāṇic statement:[22]

prayāsyanti yadā caite pūrvāṣāḍhām maharṣayaḥ /
or
yadā maghābhyo yāsyanti pūrvāṣāḍham maharṣayaḥ /
tadā nandāt prabhṛtyeṣa kalir vṛddhim gamiṣyati //

(*Viṣṇupurāṇa*, IV. xxiv. 112; *Bhāgavata*, XII.ii.32; etc.).

It is said here that when the Sages pass from *Maghā* (their position at the beginning of *Kali* when Parīkṣita was ruling) to

Pūrvāṣāḍha at the time of Nanda, the *Kali* will worsen. From *Maghā* to *Pūrvāṣāḍha* the Sages pass 10 asterisms in their course, taking the motion to be direct, (as we have established), i.e. about 1000 years from Parīkṣita to Nanda, and this is supported by two readings. But Triveda suggest 1500 years for this interval, supported by the other two readings. Counting backwards from *Maghā* or *Pūrvāṣāḍhā* (in accordance with his theory of retrograde motion) he should get 17 asterisms, not counting either *Maghā* or *Pūrvāṣāḍhā,* and at least 16, not counting both. Thus he should get at least 1600 years as the interval. But this will not suit his theory, and so he omits to count *Śravaṇa*, and gets the 15 asterisms he wants to give him the required interval of 1500 years ! (see ib., p.12, lines 10-11). This is proof that the author of the *Purāṇa*s, who employed the *Saptarṣi* Era for purposes of chronology, has taken the motion only to be direct and used the Era; and not retrograde, for if taken as such, at least 1600 years will be got as the interval, which is not supported by any reading of the text.[23]

One thing clearly emerges from this discussion, viz., the motion of the Sages as given by the astronomers and the *Purāṇa*s in direct and not retrograde. So VM can be right in saying that the Sages were in *Maghā* in the 7th cent. *Kali*, and in this he is supported by Āryabhaṭa II, and Parāśara, as well as the *Śrutarṣi*s. Therefore Yudhiṣṭhira's reign associated with the Sages at *Maghā* can well be in the 7th cent. *Kali*, also supported as it is by a whole school of chronologists. As the *Śaka* Era mentioned is to come 2526 years after this period, it is the *Śaka* of 78 A.D. that much have been meant by VM in the *śloka*, *Bṛ. Saṃ.* XIII.3, and not the one postulated by TSN etc., concurring with what we have established already in the previous study from an astronomical point of view.

IV. The Aihole inscription

Now we shall take up the Aihole Inscription and show that the *Śaka* used in it is only that of 78 A.D. and the other one alleged by TSN and echoed by certain other scholars. Disicussing the age of VM in his *Age of Śaṅkara*, Pt. I-D, pp.224ff., TSN takes up the Aihole inscription for consideration,[24] and tries to show that the *Śaka* Era mentioned

therein is his own *Śaka* of 550 B.C. from synchronism found in it between the *Śaka* Era and the *Bhārata* War. The portion of the inscription relevant to our discussion is the following:

> *triṃśatsu trisahasreṣu bhāratād āhavāditaḥ /*
> *saptābdaśatayukteṣu śa (?ga) teṣvabdeṣu pañcasu //*
> *pañcaśatsu kalau kāle ṣaṭsu pañcaśatāsu ca /*
> *samāsu samatītāsu śakānām api bhūbhujām //*

In trying to interpret this passage, Dr. Fleet at first (*IA* V 1876, 67-73) made the mistake of thinking that the time of the inscription is given in three eras, viz. the *Bhārata* War, the *Kali* and *Śaka*. Perhaps he was led into this mistake by the word '*śata*' occurring thrice (*saptābdaśatayukteṣu, śateṣvabdeṣu*, and *pañcaśatāsu*) and the statement in the *Purāṇa*s that the *Kali* epoch (1879) 240-41, Dr. Fleet acknowledged his mistake and gave the correct reading by emending *śateṣu* into *gateṣu* (for in the Kanarese-Telugu script in which the inscription is engraved on rock, *ga* with a horizontal stroke across would become *śa* and the engraver might have been misled into adding the stroke here by the large number of *śa* letters occurring in the context; or it might have been caused by weathering) and interpreting the passage as 3735 years from the *Kali* epoch, after the *Bhārata* War, and 556 years after the *Śaka* kings, i.e. 556 years in (Śalivāhana) *Śaka* Era.[25] This interpretation is accepted by all scholars (see for instance, Keilhorn, *Ep. Ind.* VI (1900-01) 1-12) except TSN and KV.[26] But the emendation of *śateṣu* into *gateṣu* is accepted by TSN. He also accepts the fact that only two dates are given, of which one is the *Śaka* Era. This necessitates the two expressions 'after the *Bhārata* War' and 'from the *Kali* epoch' to be taken together, as giving one date. If the *Kali* epoch is meant as important and the *Bhārata* War is mentioned here simply to describe it, without any more trouble we get the interpretation, '3735 years from the Kali epoch', which beautifully synchronizes with the *Śālivāhana śaka* year 556 given, (about this number there is no dispute), for if we deduct from 3735 the well-known converter 3179 we get 556, which itself proves that this must be the *Śālivāhana śaka* of 78 A.D. If on the other hand the *Bhārata*

War is taken as important, and also that the War was fought 36 years earlier (TSN makes it 38 to suit his calculations), according to one sub-school[27] taken advantage of by TSN, then there is trouble, for the war took place in 3140 B.C. according to TSN 3735 years from this date there is no *Śaka* epoch to synchronic with. But TSN sorely wants it to synchronise with the *Śaka* 550 B.C. postulated by him. He clutches at *an error committed in a collection of old records published for literary* study, the *Prācīnalekhamālā*, (N.S. Press, Bombay, *Kāvyamālā Series* 16) thinking that it will help him. In the *Prācīnalekhamālā, saptābda śata* is printed as *sahābdaśata*. Whether this is a misprint or an intended emendation, we do not know. But this we can say, that the letter is certainly *pta* and not *ha*, as anyone can verify from the photo-print of the inscription reproduced in *IA* V (1876) *op.cit* p. 69, ib. VIII (1879) op. p. 241. *Ep. Ind.* VI (1900-01) op. p.7,etc.) and comparing the letters. Not only this; the word *saha* will be a repetition, because there is the word *yukta* giving the same meaning; also *saha* requires an instrumental to govern, which is not available in the verse. In spite of all this TSN takes this *saha* instead of *sapta* and gets the number 3135, (of course, as we have pointed out, with the word *sahād* serving no purpose in the interpretation) and begins to effect the synchronization thus, (see p.189, *Plot in Indian Chronology*): The Aihole Inscription is 3135 years from the war, viz. 3140 B.C. So the date of the inscription is 3140 B.C. So the date of the inscription is 5 B.C. And then the inscription is 556 years from the *Śaka* epoch (of TSN) viz. 550 B.C. 556 years from 550 B.C. is 6 B.C. (so says TSN, for he wants it, and wish is farther to thought). 6 B.C. is only one year off 5 B.C. (obtained above), which can be easily accounted for, and the synchronism established; which shows that the *śaka* mentioned in the inscription in his *Śaka* of 550 B.C.. But TSN and KV who quotes him seem to be unaware of the blunder in the calculation, viz. that 556 years from 550 B.C., is not 6 B.C., but 7 A.D.; and this date is 11 years off and the synchronism is far from being established. What is more, having failed to prove the 550 B.C. *Śaka*, but thinking that it has been proved, TSN indulges in a tirade against Orientalists and their ways (see p. 190, *ibid*)., unconscious all the while that it all applies to the writer himself: "Alas! It is a great

pity that these Orientalists should at first conceive a theory of their own, and then actively set themselves to work out the same by hook or by crook, by changing every authority to suit their own favourite hypotheses, and by hoisting up the fabricated text as the only true version,. while they perfectly know all the while in their own heart of hearts that they have been able to achieve their objects only by fabricating evidence and meddling with the original authorities. The Orientalists simply beg the question, and beat about the bush in discussing such matters (here explanation of the word *Śaka*), blowing hot and cold at the same time, misjudging themselves, and misleading others, and thereby keeping back the Truth as far away as possible from the ken of ordinary public".

V. The Evidence of the *Jyotirvidābharaṇa*

Even though we have stated that the evidence of the *Jyotirvidābharaṇa* does not merit any consideration (*JIH* XXXVI.363) still because it is made much of by TSN, KV and VT (see for e.g., KV: *JAHRS* XXI (1950-52) 28-32, *Chronology of Nepal History,* Vijayawada, 1953, pp. 14-19: VT: *JIH* XXVIII (1950) 107-08), we shall consider that too. Their contention is that the author of the *Jyotirvidābharaṇa* is the famous Kālidāsa himself as claimed by the work, that he with VM and several other great scholars lived at Vikramāditya's court,[28] that he wrote the work in *Kali* 3068 (34 B.C.)[29] and that therefore VM cannot belong to 427 in the *Śaka* of 78 A.D. (corresponding to 505 A.D.), but only in the postulated cyrus (or *Āndhra*) *Śaka* of 550 B.C. (corresponding to 123 B.C.), and that thus the cyrus (*Āndhra*) *Śaka* is proved. But the work could not have been written before 78 A.D. (though it says it was written in 34 B.C.), for in that work *Śālivāhana* is mentioned as *śaka-kāra* (founder of an era), and that he founded the *Śaka* Era 135 years after Vikrama founded his own *Śaka* 3044 years after *Kali* (i.e. 57 B.C.).[30] How could Kālidāsa, the alleged author of the work, be the contemporary (however junior it might be) of VM (said to have lived in 123 B.C.) and at the same time know the starting of the *Śālivāhana Śaka* in 78 A.D.?

Untenability of the postulated Śaka of 550 B.C.

The late date of the *Jyotirvidābharaṇa* can be established also by other internal evidence in that work. Thus in giving the rule for the calculation of *Ayanāṃśa*, it is stated that 445 is to be deducted from the years in the *Śaka* Era and the remainder divided by 60. *Cf.*

śākaḥ śarāmbhodhiyugo-(445)-nito hṛto
mānam khatarkair (60) ayanāṃśakas syuḥ / (1.18a)

This means that in 445 *Śaka* the *ayanāṃśa* is zero. This can be only the *Śālivāhana Śaka*, for Indian astronomical works give zero *ayanāṃśa* for c. 421 *Śāli (Kali* 3600), (some give 444). It cannot be argued that the author means the postulated Cyrus Era here, because firstly among the six *śaka*s given by him he does not mention this *śaka* at all, and secondly nobody gives zero *ayanāṃśa* for this time (445 Cyrus Era would be 105 B.C.), not even VT, who, as we have seen, implies – 3° 20' *ayanāṃśa* for 123 B.C. (though he takes it as starting point for calculation) (*JIH* XXVIII.106 and our discussion or it, *JIH* XXXVI.354-57). Thus having seen that it is the *Śālivāhana Śaka* that the author uses, we can say that he is later than 445 of this *Śaka* (523 A.D.), for this rule can be applied only later that 445 *Śaka*, no instruction being given as to what to do if the time taken is before 445 *Śaka*.

Again the rule given in the *Jyotirvidābharaṇa* for finding the year in the 60 year cycle of Jupiter corroborates this.[31] If it is applied to the current year, 1881 *Śaka* (1959-60), we get the year *Virodhakṛt*, which we also get if we work it out according to the methods in the *Siddāntas*. If the year reckoned in the Cyrus Era or in the *Vikrama* Era is used in the rule, there is disagreement.[32] So it is the *Śālivāhana Śaka* that is required to be used in this rule and not the Cyrus *Śaka* not the *Vikrama Śaka* which reigned in his time (for he says he is a contemporary of *Vikrama*). Thus again the conclusion that the author is later than the starting of the *Śālivāhana Śaka* follows.

In answer to these objections KV seems to have argued that Kālidāsa could actually have lived earlier than the *Śālivāhana Śaka* epoch and have mentioned that epoch as a future historical event on the basis of the *Śāstras*[33] (evidently meaning the *Bhaviṣyapurāṇa* etc.). But then how did the *Śāstras* know? Does KV want us to believe that

they actually predicted future events? Clearly the *Śāstras* themselves should have been written after the *Śālivāhana Śaka* epoch, and the *Jyotirvidābharaṇa* should be later still. And then the jumbling together of people of various ages already alluded to! We are asked to take this bundle of lies as sober history !

In the same manner other romances, (there is no dearth of them) based on popular stories should be dismissed wherever they contradict what may be judged as solid evidence, for we do not know who their authors were, nor what equipment they had for giving historical facts.

VI. Conclusion

Thus in all places where the word *Śaka* is used for the name of an era, it is the *Śaka* of 78 A.D. (what latterly came to be called *Śālivāhana Śaka*) that is meant. Further there is no evidence to show that an era was started in 550 or 551 B.C. in Persia or in India as postulated by TSN and accepted by KV, which he calls the Cyrus Era, or as postulated by VT, which he calls the *Āndhra* Era. It may be that Cyrus founded the Persian Empire in 550 B.C., but what evidence is there to show that he started an era then? No such era was in use in Persia itself, not to speak of India. Many great events happen in the reigns of great kings. But they are not necessarily the starting points of eras. (VT does not even mention a great event in 550-51 B.C. for the starting of his *Āndhra* Era). Now these people have taken all this trouble in order to prove the antiquity of the Indian dynasties and in so doing to reconcile texts of varied historical worth. Let them by all means attempt it, for it is only too true that unconscieous prejudice has had some hand in the writing of the history of our land. But what we wish to show here is that their stand on the interpretation of the term *Śaka* Era, with its ramifications, is wrong, and will not help them, as also the various other ideas of theirs, which we have shown to be wrong. Also we wish to point out that attributing base motives and questioning the bonafide people (the writings of TSN and KV are replete with these) will not only not help, but may also be "paid back with interest", as Dr. Kane says.

NOTES AND REFERENCES :

1. In the same way we can easily see that the date of Bhāskara II's work, the *Siddhāntaśiromaṇi*, is 1150 A.D., from his statement:

   rasa-guṇa-pūrṇa-mahī(1036) sama Śaka-nṛpa-samaye 'bhavan mamotpattiḥ / rasa-guṇa (36) varṣeṇa mayā Siddhānta Śiromaṇī racitaḥ //

2. There is one other place where VM mentions the *Śakakāla*, viz. *dvyūnam Śakendrakālam* etc.

   (*Pañcasiddhāntikā*, XII,1), which we have not taken for discussion. This mention is in connection with the rough *Paitāmaha Siddhānta*, and as no useful purpose will be served by discussing it, and as it is not taken into consideration by TSN etc,. also, we have left it out.

3. This is the reason why this stanza has not been taken as VG's by other scholars also. For e.g. Colebrooke writes: 'The commentator, Bhaṭṭotpala, supports the text of his author (viz.VM) by quotations from VG and Kāśyapa; 'At the junction of the *Kali* and *Dvāpara* ages', says Garga, 'the virtuous Sages ....stood ....'at *Maghā*' (*Miscellaneous Essays*, London, 1873, vol. III, p. 313). Cunningham writes: 'His (VM's) words are... 'The Seven Seers etc.' But unluckily for VM, his commentator Bhaṭṭa Utpala has given us the very words of Garga, who simply says, 'At the junction of the *Kali* and *Dvāpara* ages the virtuous Sages .... stood at the asterism over which the *Pitṛs* preside, that is, *Maghā*'. On comparing this quotation with Varāha's statement (in the stanza in question) we see at once that he (VM) has suppressed Garga's mention of the *Kaliyuga* ....' (*Book of Indian Eras*, Calcutta, 1883, pp. 9-10). This shows that Cunningham considers that VM is not quoting the stanza, but that it is VM's own. P.V. Kane says: 'In the preceding verse VM says that he will declare the motion of the seven sages by deriving it from the doctrine of VG. The first mistake of the writer (It is KV that he refers to here) is to hold that verse XIII.3 came originally from *Garga Saṃhitā*. Really it is VM's own verse. Utpala quotes the verse of VG, on this point, which is in a different metre, though the meaning is the same as the first half of XIII.3.' (*JAHRS* XXI (1950-52) 41).

4. *Vide* i. Jinavijaya, *'ṛṣir vāras tathā pūrṇam martyākṣau* (2077) *vamamelanāt*', *'nandāḥ pūrṇam bhūś ca netre manujānām* (2109) *ca*

vāmataḥ' quoted by TSN in his *Age of Śaṅkara*, (Madras, 1916 ff.), Pt. I, ch. iii, pp. 139 and 141, and also his adding 468 to get the years in the *Kali* Era. ii. Kota Bhaviah Chowdary's statement: 'According to Jain authorities Yudhiṣṭhira was crowned in 2634 B.C. only. ... From Purāṇic *Kaliyuga* (of 3102 B.C.).... 468 years passed upto Yudhiṣṭhira'. (*JAHRS*. XXII (1952-54) 53. *Cf.* also Cunningham, Book of Indian Eras, p. 7, where he speaks of *Abul Fazl* giving in his Ain-i-Akbari three views on the subject, of which one is that the reign of Kaṃsa, (uncle of Lord Kṛṣṇa and so contemporary of Yudhiṣṭhira) was 'above 4000 years before the fortieth of Akbar' , (i.e. 1595 A.D.), that is between 2400 and 2500 B.C. This would give Yudhiṣṭhira a date about 2407 B.C. or the 7th cent. in *Kali*.

5. The inscription in the temple of Hanumān at Jaisalmer, Rajaputana, gives a date in this era. The speech of Hanumān in the *Mahābhārata*, *Vanaparva*, ch. 151, verse 39 (Kumbhakonam edn.) containing the words, *etat Kaliyugam nāma acirād yat pravartate*, and Kṛṣṇa's excuse for the unfair fight with the words *prāptam Kaliyugam viddhi* (ib. Śalyaparvan, ch. 61, verse 27) support this. Abul Fazl expresses another view that the Mahābhārata War was fought 4801 years before the 40th years of Akbar's rule and 105 years before the end of the Dvāpara age. (see ib.).
6. Eg. the Aihole Inscription. See discussion *infra* for details. This view is mentioned also by Abul Fazl, which is 4696 years before the 40th year of Akbar's rule. (see ib).
7. The *Purāṇas* express this view; *cf.*

   yasmin kṛṣṇo divam yātaḥ tasminn eva tadāhani /
   pratipannaḥ kaliyugaḥ tasya saṅkhyām nibodhata //

   Brahmāṇḍa Purāṇa, ch. 74, verse 241 (Venk. Press edn.) Vāyu has the same reading. *Viṣṇu, Matsya* and the *Bhāgavata* have almost the same reading.
8. The words in the *Āryabhaṭiya*, *Gurudivasāc ca bhāratāt pūrvam* (*Gītikā*, 5), which is explained by Parameśvara as 'the day of the *Mahā-prasthāna*'., support this.
9. In fact nowhere does VM say that the Sages were at *Kṛttikā* at the beginning of *Kali*. This must be an inference of Cunningham when he

gives *(cf.* Table on p. 17 of his Book of Indian Eras) 3177 B.C. for the beginning of *Kṛttikā* according to VM, inference from the fact that according to him the Sages passed to *Maghā* in the 7th cent. after *Kali* (cf. same Table). TSN and KV seem to have simply taken Cunningham's statement as true without question. They only object to Cunningham's treating the motion as direct, while according to them it is retrograde. But they fail to see that if the motion is retrograde, the Sages should be at *Anurādhā* (and not at *Kṛttikā*) at the beginning of *Kali* if they are to come to *Maghā* seven centuries later. Thus Cunningham's inference would be wrong and their acceptance of it would also be wrong.

10. The following are the names of the Sages, with their Right Ascension and Declination for c. 1900 A.D.: (i) *Kratu* (Alpha Uras Major) 10^h 58^m, +62° 17'; (ii) *Pulaha* (Beta Ursa Major) 10^h 56^m, +56° 55'; (iii) *Pulastya* (Gamma Urṣa Major) 11^h 49^m, +54° 15'; (iv) *Atri* (Delta Ursa Major) 12^h 10^m, +57°; (v) *Aṅgiras* (EPSilon Ursa Major) 12^h 50^m,+56° 30'; (vi) *Vasiṣṭha* (Zeta Ursa Major) 12^h 50^m, +56°; (vii) *Marīci* (Eta Ursa Major) 13^h 44^m, +49° 49'. For comparison we shall give the asterisma belonging to the corresponding ecliptic segment: *Maghā* (Alpha Lenois) 10^h 3^m, 12° 27'; Pūr. Phal. (Delta Lenois) 11^h 9^m, 21° 4'; Ut. Phal. (Beta Lenois) 11^h 44^m, +15° 8'; *Hastā* (Beta Corvi) 12^h 29^m, -22° 51'; *Citrā* (Alpha Virgo) 13^h 20^m, - 0° 38'; *Svāti* (Alpha Bootes) 14^h 11^m, +19° 42'

11. A number of explanations can be given as to how this wrong theory of motion could have originated, but as this is beside the point, we stop with saying this much. Some people believe in the reality of this motion and try to explain it accordingly, using the theory of the Precession of the Equinoxes. For e.g. (i) VT says that because the Celestial Pole moves in a small circle once round the Pole of the Ecliptic in about 27,000 years, the point of inter-section of the Ecliptic with the line joining it and the mid-point of the first two stars constituting the Sages also moves. As the Sages are said to be at this point of interesection, they are also considered to move (see his *Popular Astronomy*, Madras, 1958, pp. 138-40). But this simulated motion can be only a small fraction of the value of the motion according to the *Saṃhitās* which is as great as 13° 20' per century. Also while the *Saṃhitās* say that the motion is uniform and traverses the ecliptic completely, this simulated

motion will not be uniform, and will be oscilatory and restricted to a small segment of the ecliptic. Thus it will be forward and backward, the former during the past 7,000 years and more, against the opinion of VT (cf. ib. p. 139) who says that the motion is retrograde like that of the *First Point of* Aries.

(ii) Prof. R. Krishnamurti (according to VT, ib 139-40) holds the view that the extent of the Sages in longitude is about a tenth of the ecliptic. This extent is divided into 27 equal parts, each part 'symbolically' forming a *Nakṣatra*. The traversing of these 27 symbolic *Nakṣatras* will take 2700 years. If it is taken that the other 9 segments also are so divided, it will take 10x2700 = 27,000 years for traversing the whole ecliptic. The authority for this symbolic division is found in the following stanza:

śatam te rājan bhiṣajas sahasram urvī gabhīrā sumatiṣṭe astu /
bādhasva dūre nirṛtim parācaiḥ kṛtam cidenaḥ pramumugdhyasmat //
amī ya ṛkṣā nihitāsa uccā naktam dadṛśe kuhacid diveyuḥ /
adabdhāni varuṇasya vratāni vicākaśac candramā naktam eti //
ṚV I.24.9-10

But what have these *ṛks* in prayer of Varuṇa to do with the alleged symbolic division? What flight of imagination can create the idea of the symbolic division of the ecliptic from the two words *śatam* and *sahasram* in one sentence, and the word *ṛkśā* in quite a different sentence? And then Prof. Krishnamurti seems to suggest that the motion of the Sages is only another name for the phenomenon of Precession, artificialised for the purpose of chronology.

(iii) Dr. D. S. Triveda (*JIH* XIX (1940) 9-12) confuses the motion of the Sages with Precession itself and says that the ancient ṛṣis, far older than the *Saṃhitākāras* had discovered a cycle of 27,000 years for the motion (the same as for Precession), but by the time of the *Saṃhitākāras* one cypher was lost, and the period was mistaken as 2700 years! He does not mention how Precession simulates the motion of the Sages.

12. We do not know when these eras were founded. The *Purāṇas* say that 25 years after *Kali* set in the Sages who had been at *Maghā* for a 100 years left it for the next asterism. The dates of the dynasties of kings

are given in terms of the situation of the Sages in the different asterisms. The *Laukika* Era is the same as the *Saptarṣi* Era with the number of the year in each century being generally used and the centuries or the reference to the asterisms omitted. This is used in the *Rājataraṅgiṇī* to give the dates of dynasties and kings, as also the date of the work.

13. *Vide* Colebrooke, ib., p. 316 _ 17: ... a probable inference may be thence drawn as to the period when these authors lived, provided one position be conceded; namely, that the rules, stated by them, gave a result not grossly wrong at the respective periods when they wrote. Indeed it can scarcely be supposed that authors, who, like the celebrated astronomers in question, were not mere compilers and transcribers, should have exhibited rules of computation, which did not approach to the truth, at the very period when they were proposed.

14. Because the Sages are always to be seen within this limit. Though strictly speaking the position of the first two stars are to be taken into consideration, still in practice the situation of the whole group must have been vaguely taken as the position. The Sages are said to be at the asterism where the declination circle passing through the mid-point of the two front stars (*Pulaha* and *Kratu*) that rise first, cut the ecliptic. This would give a position beyond *Maghā* and near *Pūrva Phalgunī*, at present. (But in ancient times *Maghā* might well have been the position on account of the Celestial Pole having been a little more to the East of its present position.) But it seems that later on it came to be considered that the asterism against which the Sages are seen generally is the position. Thus we can get *Pūrva Phalgunī, Uttara Phalgunī, Hastā* or *Citrā*. The rule may also be interpreted as the segment which is seen to rise together with the two front stars. If this interpretation is accepted, we can get on account of cara (oblique ascension) any asterism from *Kṛttikā* to *Maghā* as the position for observers in North India according to their latitude.

15. The idea of the retrograde motion must have originated very late, the reason being that it can at that period serve to reconcile faith in the theory of the motion with observation. (Giving various positions like *Maghā, Kṛttikā, Rohiṇī, Śravaṇa*, to the Sages at the beginning of

Kali, giving different rates of motion, and being satisfied with rough positions, are evidently only different means of effecting this reconciliation.) The Pandits of Banaras who informed Col. Wilford in c.1804, believed in the retrograde motion. The *Kaliyugarājavṛttānta*, (Bhāga III, ch. iii), as quoted by TSN, KV and VT, undoubtedly believes that the motion is retrograde, by stating that 25 years after *Kali* set in, the Sages left Maghā for *Āśleṣā* (See *Age of Śaṅkara,* Pt. I, App. 139ff; *JAHRS* XX 69ff; *JAHRS* XXII 169-70). But as can be seen from the dynasties it deals with, it is a recent work, and cannot command authority like the *Purāṇas*, for the author of this work is only like one of us trying to reconstruct ancient history from Purāṇic evidence.

16. For c.700 A.D. the position of the Sages would be *Citrā*, which being within the limit of observation, we can conclude that the date of Āryabhaṭa II is c. 700 A.D. Though a date within three centuries earlier is possible, it is not likely; a date as late as can be within the possible period has to be fixed for Āryabhaṭa II on other grounds.

17. For details see *Mahāsiddhānta*, Ed. Sudhakara Dvivedi, Banaras, 1910, Contents in English, pp. 1-4. See also Cunningham, ib., p.8.

18. Obviously, the probable date of Parāśara would also be c.700 A.D. or within some three centuries earlier. This would give sufficient time for Āryabhaṭa II to refer to Parāśara's views in his work.

19. Lalla uses the word *viriñci* (a synonym for Brahmā or Prajāpati). All but Munīśvara take this as *Rohiṇī*, and this would give the Sages a position agreeing with observation in Lalla's time, c.650 A.D. But Munīśvara, in order to make it agree with his own observation, takes it as *Abhijit* (whose deity is Vidhi, another synonym for Brahmā,) which is almost the same as *Śravaṇa*. Naturally Munīśvara is unaware that for Lalla's observation it is *Rohiṇī* that would give the agreement. He seeks support for his interpretation from *Śākalyasaṃhitā, Praśna* II, ch. ii, the statement, 'Kratu was at Viṣṇu's star at the beginning of *Kali*.'

20. It has been shown in the Introduction to the *Mahābhāskarīyam* (Ed. T.S. Kuppanna Sastri, Madras, 1957), p. xviii, that Lalla is later than Brahmagupta, having commented upon his *Khaṇḍakhādyaka* and so he could not have been a disciple of Āryabhaṭa I, and so, much earlier than 650 A.D.

21. *Cf.* his artcle, *'The Intervening Age between Parikshit and Nanda'*, *JIH.* XIX. (1940) 1-16.

21a. See the text and the variants recorded by Pargiter, *The Purāṇa Texts of the Dynasties of the Kali Age,* O.U.P. 1913, p. 58.

22. See Pargiter, *ib.* p. 62. In the place of this line mentioning *Pūrvāṣāḍhā,* the *Kaliyugarājavṛttānta* gives : *śravaṇe te bhaviṣyanti kāle nandasya bhūpateḥ.* This is not supported by any Purāṇic source and hence not fit to be taken astronomy authority.

23. On page ... of this article Triveda gives a tabular statement of the chronology. There he counts *Śravaṇa,* but to compensate for the extra 100 years that would occur, gives the period 3233 to 3133 B.C. for *Maghā* and 3133 to 3076 B.C. for *Āśleṣā* (thus giving only 57 years for *Āśleṣā* instead of 100 against the *Purāṇas* that give 3176 to 3076 B.C. to *Maghā,* 3076 to 2976 B.C. for the next star, and so on. Triveda's scheme is supported by no *Purāṇa.*

    Incidentally we may mention another mistake he employs to achieve his purpose. He wishes to give 1724 A.D. to 1824 A.D. for *Svāti,* so that his table might agree with the statement of Wilford's Pandits of Benares who have told that the sages were at *Svāti* in 1804 A.D. So he includes *Abhijit* among the *nakṣatras* counted and gives for it the century 1024 to 1124 A.D. (see p... , apparently unware of the fact that this trick would make the cycle last 2800 years instead of the usual 2700 years, and that he himself has not counted it in the previous cycle (see p...). If this kind of shift is resorted to one can prove anything.

24. We have not had access to this section of TSN's work. Our authority is the long quotation in KV.'s plot in *Indian Chronology,* Ch. X. 185-90.

25. This era is variously given astronomy *śakānāṃ nṛpāṇāṃ* (or *bhubhujām*) *kāla, śakanṛpati* (or *bhūpa*) *kāla, śakendrakāla,* in the earlier centuries, and as *Śālivāhana Śaka* later. The origin also is attributed to varius causes: *e.g.* as named after the good rule of the *Śaka* kings (Govindasvāmin's *Bhāṣya* on *Mahābhāskarīya),* the destruction of the *Śaka*s by Vikrama (Bhaṭṭotpala commenting on *Bṛ. Saṃ* VIII. 20) after Śālivāhana who established his rule (later commentators and tradition).

26. After siding with TSN in *The Plot of Indian Chronology,* ch. X, and speaking with some variation in *JAHRS.* XXI (1950-52) 52-53, K.V. has changed over to the correct interpretation in his note , *'The Aihole Inscription of Pulikesin'* (*JAHRS.* XXII (1952-54) 210-12, wrongly numbered 206-08) without a word of regret for having talked and questioned the bonafides of the very persons to whose opinion he has now been converted. On p. 212, he still seems to be unaware of the fact that Dr. Fleet has corrected himself long ago.
27. *See* fn. 7 *supra*. Note that there is still another sub-school that takes the war synchronous with the *Kali* epoch. Obviously according to this school also, the interpretation is what we have already mentioned astronomy the correct one.
28. *Cf.* the verse *Dhanvantari-kṣapaṇaka* etc, *Jyotir.* XXII. 10.
29. *Cf.* verse

    sindhuradarśanāmbaraguṇair (3068) *yāte kales sammite /*
    māse mādhavasaṃjñake ca vihito granthakropakramaḥ // XXII. 21.
30. *Cf. Jyotir.* X. 110-11, giving the several Eras of the *Kali* Age : (i) *Yudhiṣṭhira* Era for the first 3044 years, (ii) *Vikrama* Era for the next 135 years, (iii) *Śaka* Era for the next 18000 years, (iv) *Vijayābhinandana* Era for the next 10,000 years, (v) *Nāgārjuna* Era for the next 4000,000 years and *Bali* Era for the following 821 years.
31. *Cf.* The rule : *nagair nakhais sannihato*

    dvidhā śaka saktatriśakro 'kṣayamāṅgabhājitaḥ /
    gatāptatallabdhaśako 'bhraṣaḍhṛto-
    'vaśeṣake syuḥ prabhavādivatsarāḥ // 1. 16

    it means : Do the operation , { (7x + 20x 60+1430)÷ 625 +x } ÷ 60, where x is the *Śaka* year gone. Get the remainder. Count years from *Prabhava* equal to this remainder and the *Prabhavādi* year is got.
32. This kind of work we have already done, when dealing with Prof. Gulshan Rai (*JIH.* XXXVI. 365-66)
33. *Vide* his letter to Kottah Bhavaiah Chowdary referred to in *JAHRS.* XXII. 55.

KOLLAM ERA*

Kollam era, called also Malabar era, is reckoned from August 15, 824 AD. Unlike most other Indian eras in which: (i) the year is luni-solar or lunar, (ii) commences from *meṣa-rāśi* (sign Aries), and (iii) the year-number refers to the 'expired' year, the *Kollam* era is entirely solar both with regard to the year and to the twelve constituent months, the year-number refers to the current year, and the year commences from the *siṃha-rāśi* (sign Leo). The era is called *Kollam* era on account of its having been inaugurated at the city of *Kollam* which is situated in Kerala on the West coast of India, and is called Malabar era after the region where it was and is still prevalent. The numerical notation used for digits in expressing astronomical constants and computation is according to the *Kaṭapayādi* system as against the *Bhūtasaṅkhyā* system prevalent in the other parts of India. In spite of the prevalence of legendary accounts, historically, the era was inaugurated by King Udaya Mārtāṇḍa Varmā at his capital city of Kollam after elaborate consultation with his court astronomers who were devoted to the study and propagation of the discipline of astronomy.

Key words: *Bhūtasaṅkhyā*, *Kaṭapayādi* system, *Keraḷolpatti*, *Kollam* era, Malabar era.

Commencement and conversion formula:

Kollam era commenced on a date corresponding to August 25, 824 AD. There again, it is 'solar' and 'current' (as against 'expired'). From the time of the acceptance of Pope Gregory's compensation of 10 days to the Julian era, in 1582, the commencement of the *Kollam* years has shifted to August 15 of the Christian year. The formula for conversion would then be A.D. date = *Kollam* date + 824 (for August 15 to December 14) and *Kollam* date + 825 (for December 15 to August 14). It is also to be noted that while the above is the case for the major part of Kerala, comprising of South and Central Kerala, in North Kerala the era is reckoned from the next month, *Kanyā*, i.e. from September 25/15 instead of from August 25/15.

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This era is called *Kollam* era since it is purported to have been inaugurated in the city of *Kollam* on the West coast in Kerala. It is also called '*Malabar*' era on account of its being prevalent in Malabar. In Sanskrit texts, the era is termed *Kolamba*. The prevalence of the era extended to the adjoining districts of Tirunelveli and Madurai in Tamilnadu and part of Śrīlaṅkā. It is described as a 'current' era for the reason that, unlike all purely Indian eras, such as *Kali, Śaka, Saṃvat,* Bengali Saṃ and others, which are all expressed by their 'expired' years, and wherein one has to add 1 to the year number to get the number of the 'current' year, *Kollam* era alone, is expressed in its current years like the Christian era, A.D.

The *Kollam* era is 'solar' for the reason that unlike several other eras which are either lunar or luni-solar, necessitating the application of *adhika-māsa* (additional month) and *nyūna-māsa* (deleted month), in the *Kollam* era, the months are purely solar, as reckoned from *Saṅkrānti* to *Saṅkrānti* (Sun's transit), i.e., from the moment when the sun enters a *rāśi* (sign of the zodiac) to the moment when it leaves that sign and enters the next, and, in this manner, through the twelve signs of the zodiac.

In *Kollam* era, the years commence with the *Siṃha-rāśi* (sign Leo) and not with *Meṣa-rāśi* (sign Aries) as in most other systems. Naturally, the year ends with *Kaṭaka-rāśi* (sign Cancer). The days are reckoned from one local sunrise to the next. Since the *Saṅkrānti*-s need not coincide with sunrise and can occur any time in the day or night, a convention has been adopted to the effect that if the *Saṅkrānti* occurs within 18 *nāḍikā*-s from sunrise, then that day would be taken as the first day of the new month and if after 18 *nāḍikā*-s, that day would be taken as the last day of the current month, and the next day would be taken as the beginning of the next month. On account of this system of reckoning the number of days in a month varies from 29 to 32.

Kollam Era and local Parlance

Being prevalent in the Malayalam speaking region of the land, certain words and expressions in the Malayalam language would be used when the years in the era are mentioned in manuscripts and inscriptions. It is therefore necessary to know the common expressions used in such contexts.

The year is mentioned as just *Kollam* or with the addition of a word meaning 'year' like *varṣa* or *āṇḍu* in Malayalam and *abda* in Sanskrit.

The twelve months, all solar, of the year are:

1, *Ciṅṅam* (*Siṃha*, August-September)
2. *Kanni* (*Kanyā*, September-October)
3. *Tulām* (*Tulā*, October-November)
4. *Vṛścikam* (*Vṛścika*, November-December)
5. *Dhanu* (*Dhanus*, December-January)
6. *Makaram* (*Makara*, January-February)
7. *Kumbham* (*Kumbha*, February- March)
8. *Mīnam* (*Mīna*, March-April)
9. *Meṭam* (*Meṣa*, April-May)
10 *Iṭavam* (*Ṛṣabha*, May-June)
11. *Mithunam* (*Mithuna*, June-July)
12. *Karkaṭakam* (*Karkaṭaka*, July-August)

The days of the week are : *Ñāyar* (Sunday), *Tiṅkaḷ* (Monday), *Cevvā* (Tuesday), *Budhan* (Wednesday), *Vyāḷan* (Thursday), *Veḷḷi* (Friday) and *Śani* (Saturday). The term *vāram* means 'week' and *tīyati* / *āḻca* means date/day.

The under mentioned examples will illustrate the manner in which dates are mentioned in manuscripts and inscriptions:

Manuscripts:

i. "820-*ām āṇṭu meṭam 28-ām tīyati...*"

(Ms. of *Laghubhāskaraīya*, Trivandrum Palace ms. No. 943)

ii. "...905-*ām āṇṭu kanni-māsam 13-ām tīyati śani-āḻcayum apara-navamiyum...*"

(Ms. of *Kumārakalpamālā*, Trivandrum Palace ms. No. 943)

Inscriptions:

i. "*Svasti śrī.Kollam tonri 148-āmāṇṭu tulāttiḷ vyāzhan ninra viruccika ñāyitru...*"

(Māpaḷḷi plate of Śrīvallabhan-kota, King of Veṅāḍu. *Travancor Archaeological Series*, (*TAS*), 4 (1923) 1-11.[1]

'Hail prosperity, In the year 148 after the appearance of the *Kollam* (era), in this day of Sunday, in the month of *Vṛścika*...' [2]

ii. "*Svasti śrī. Kollam tonri 336-māṇṭu iṭapa-ñāyiru añcu cenra śani-makayiram nāḷ*..." (*TAS*) 7(1930) 1-2

"Hail prosperity, In the year 336 after the appearance of the *Kollam* (era), in the month of *Vṛṣabha*, days passed 5, Saturday, (under the asterism) *Mṛgaśīrṣa*..."

Kaṭapayādi notation

An understanding of the *Kaṭapayādi* notation of expressing numbers is essential in this context for the reason that in early Kerala texts and manuscripts dates are mostly expressed in this notation. The use of *Bhūtasaṅkhyā*[3] notation is seen only rarely.

The *Kaṭapayādi* is a facile system of notation wherein the letters of the Sanskrit alphabet are used to represent the nine digits and zero. The generally meaningful words formed by putting together appropriate letters represent the full number. The system is used not only to represent dates but also numbers that occur in mathematical and astronomical texts. The letters are written from right to the left to form the number.

The system takes its name form letters *ka -ṭa - pa - ya* which are taken to represent the digit 'one' and the further letters in the respective groups commenced by ka, ṭa, pa and ya to represent the further digits. Thus:

1	2	3	4	5	6	7	8	9	0
ka	kha	ga	gha	ṅa	ca	cha	ja	jha	ña
ṭa	ṭha	ḍa	ḍha	ṇa	ta	tha	da	dha	na
pa	pha	ba	bha	ma					
ya	ra	la	va	śa	ṣa	sa	ha	ḷa	

The vowels, standing alone, represent zero and consonant standing alone, i.e., not followed by a vowel, does not represent any digit. Note that the latter '*ḷa*' which is included in the Kerala/Malayalam alphabet represents the digit '9'.

There are two definitions for the *Kaṭapayādi* notation:

1. *na- ñāv-acaś ca śūnyāt; saṅkhyāḥ kaṭpayādayaḥ /*
   miśre tūpāntya-hal saṅkhyā; na ca cintyo hal asvaraḥ //

'*na, ña,* and the vowels (acaḥ) (represent) zero, *ka, ṭa, pa, ya* and the letters following them represent the digits. In a conjuct consonant, th penultimate consonant (hal) represents the digit. A consonant (standing alone), without a vowel following, is to be discarded (as representing no digit).'

2. *kaṭapya-vargabhavair iha piṇḍāntair akṣarair aṅkāḥ /*
   ne ñe śūnyam jñeyam tathā svarāḥ kevale kathitāḥ //

Numbers are denoted, herein, by groups of letters formed by Ka, ṭa, pa, ya and the letters (commencing) from them. Na and ña are to be understood as (representing) zero; so also pure vowels (i.e., when not attached to consonants).

The system is especially useful in coining numbers cogently and meaningfully, and fitting them unobstrusively in verses, Formulae are easily remembered. There is also the facility for the same number being 'lettered' differently to suit different metres of verses, if needed. For instance, the under mentioned verse describes a flooded river and people living on the banks fleeing, and, at the same time, the four quarters of the verse express the same *kali* date expressed by the differently 'lettered' expressions:

nadīpuṣṭir asahyā nu
ṅahy asāram payo 'jani /
nijāt kuṭīrāt sāyāhne
naṣṭārthāḥ prayayur janāḥ //

In ordinary parlance, the verse would mean:

'The flood in the river was unbearable. There came down an abundance of water. By the evening the people (living on the banks) fled from their houses, having lost all their possessions.'

And, in *Kaṭapayādi* notation, the same number is given by all the four quarter-verses, the odd line being read from left to right and the even lines read from right to left.

nu	hyā	sa	a	ṣṭir	pu	dī	na
na	hya	sā	ram	pa	yo	ja	ni
ne	yāh	sā	rāt	ṭī	ku	jāt	ni
n	ṣṭār	thāḥ	pra	ya	yur	ja	nāḥ
0	1	7	2	1	1	8	0

In Kerala, while in mathematical and astronomical texts the Kaṭapayādi notation is extensively used for sine and other tables and for depicting computational procedures, in other texts it is used in colophonic and other verses to denote dates relating to the authors or the works.

For example, in the line:

'*vidyātmā svar asarpad*' *adya bhavatām ādhārabhūr acyutaḥ*

The expression '*vidyātmā svar asarpad*' ('that learned soul passed to heaven') represents in *Kaṭapayādi* notation, (17, 24, 514) which gives the *Kali* day of the death of Acyuta, the author named in the verses.

In the concluding verse of Acyuta's *Uparāgakriyākrama*:

proktaḥ pravayaso dhyānād'
jyeṣṭhadevasya sadguroḥ /
vicyutāśeṣadoṣeṇety
acyutena kriyākramaḥ //

The expression '*proktah pravayaso dhyānād*' (17, 14, 262) gives the date of composition of the work by the author.

Folio Numbers In Manuscripts

In the present context of discussing manuscripts, a mention might be made also of a peculiar notation adopted in Kerala for numbering the folios the palm-leaf manuscripts. According to this system, the number 1 is represented by na; 2 = nna; 3 = nya; 4 =ṣkra; 5 = jhra; 6 = hā; 7 = gra; 8 = pra; 9 = dre; 10 = ma; 11 = mana; 12 = manna;...20 = tha; 30 = la; 40 = pta; 50 = ba; 60 = tra; 70 = tru; 80 = cha; 90 = ṇa; 100 = ña. While the above notation is used only for

numbering folios on the left margins or their obverse sides, normal Malayalam integers are used for representing numbers occurring in the text proper.

Legendary Origin:

There are several accounts current, recorded and hearsay, about the commencement of the *Kollam* era.

One tradition according to one of the legendary texts on Kerala, called *Keralolpattis*, alleges the introduction of *Kollam* era to Śaṅkarācārya, the exponent of the Advaita philosophy. On this it is said: "Of other customs peculiar to Malabar there is a list of sixty-four, ... These sixty-four rules are called the Kerala *Anācāram*, that is, irregular customs of Kerala; and one tradition alleges that Śaṅkara Ācārya promulgated them at *Kollam* on August 25, 824 AD, the first day of the first year of the *Kollam* era followed on the coast. There is some colour for this tradition in the well-known chronogram marking the commencement of the *Kollam* era, viz.,

0	6	1	4	3	4	1
Ā	cār	ya	vā	ga	bhed	yā

which means, 'Ācārya's (i.e. Śaṅkarācārya's) word or law is unalterable or must not be changed. The syllables represent figures as shown above (according to the *Kaṭapayādi* notation), and these written backwards give the age of the *Kali yuga* on the first day of the first *Kollam* year.' (Logan, 1989, pp. 155-56)[4]. *Kali* day 14,34,160 would work out to September 25, 824, which corresponds to the beginning of the *Kollam* era in North Malabar, i.e. the first day of the solar month of *Kanyā*.

Still another story in a different legendary work also call *Keralotpatti*, states that the *Kollam* era was commenced from the date on which the then king of Kerala, Cermān Paḷḷibāṇa Perumāḷ adopted the religion of Islam and set sail from the port of Pantalāyani-Kollam in North Malabar. (Logan, *ibid*, pp. 192-96, 230-32, 240-43).

Another account runs thus: "In the *Kali* year 3926 (824 AD), when King Udaya Mārtāṇḍa Varma was residing in Kollam (Quilon), he convened a council of all the learned persons of Kerala with the object of introducing a new era, and after making some astronomical researches, and calculating the solar movements throughout the twelve signs of zodiac and counting scientifically the number of days occupied in this revolution in every month, it was resolved to adopt the new era from the first of Chiṅṅam of that year August 15, A.D. 824, as *Kollam* year one, and to call it the solar year.[5]

"This arrangement was approved by all the wise men of the time, and every neighbouring country began to adopt the same." (Menon, 1985, pp. 88-89)[6].

Studies on the above divergent accounts have exhibited some historical discrepancies or contradictions of each of them obviousy, these legends have been concocted round personages or events of the times. What remaiṇs in them is the fact of the era to have commenced on August 25, 825 AD.

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3. By *Bhūtasaṅkhyā* ('Object numerals') is meant the use of objects having specific numerative quality to express numbers. Thus *indu*, 'the one moon represents the digit/number 'one', *akṣi*, the two eyes, represent 'two', *agni*, the three sacrificial fires represent 'three', *dik*, the ten directions i.e., the eight quarters and above and below, represent 'ten' etc.

4. Logan. William: Malabar, Reprinted, 1989, Asian Educational Services, New Delhi.

5. Pillai, L.D. Swamikannu: *Indian Chronology*, Madras, 1911.

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ASTRONOMY AND MATHEMATICS IN MEDIEVAL INDIA : SOME HIGHLIGHT*

Introductory

In the history of astronomical science in India, the medieval period is, perhaps, the most important, not only from the point of view of fecundity but also from the point of view of the progress of astronomicl thought. It is true that speculations in astronomical phenomena had a distinct place even during Vedic times, as recorded in Vedic and Brahmanic literature. *Vedāṅga Jyotiṣa,* the astronomical ancillary of the Vedas, provides the basis of the Vedic Calendar, while the *Śulba-sūtras,* the basis of Vedic mathematics, especially of geometry. This has been followed by the Jainistic speculations and theories on astronomy and, later, by the early *Siddhānta* summarized in the *Pañcasiddhāntikā* of *Varāhamihira* (A.D. 505). Āryabhaṭa wrote his masterly treatises, viz., the *Āryabhaṭīya* (A.D. 499) and the last treatise on the *Ārdharātrika* system, which form an important landmark in the development of astronomy in India. The medieval era of Indian astronomy may be said to take off from Āryabhaṭa and extend, in its First phase, from about A.D. 500, being the time of Āryabhaṭa, to about A.D. 1200, the time of Bhāskara II, and, in its Second Phase, from A.D. 1200 to A.D. 1800, when modern astronomy from Europe began to have its direct impact on India.

Development during the First Phase : A.D. 500-1200

In the First Phase of the medieval era astronomy saw the acme of development in India. It is characterized by the advent of several schools in the discipline. First, there was the school of Āryabhaṭa, which, on account of the superiority of its parameters and novel innovations, was highly popular both in North and South India. Subsequently, on account of the onslaughts of certain astronomers like Brahmagupta, its popularity in the North waned, but its sway in

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the South reigns supreme even today. A large number of commentaries, of which about twenty are available today, have been written on the *Āryabhaṭīya,* and of these as many as ten are by Kerala astronomers. A host of treatises also came to be composed by the Āryabhaṭan school of astronomers, either based on the *Āryabhaṭīya* or inspired by it. The most important among these are the *Mahābhāskarīya* and the *Laghubhāskarīya,* both by Bhāskara I (A.D. 629), the *Grahacāranibandhana* of Haridatta (A.D. 658-700), being the basic text of the *Parahita* system of astronomy of Kerala, the *Karaṇasāra* of Deva (A.D. 689), and the *Vaṭeśvara-siddhānta* (A.D. 904). The *Khaṇḍakhādyaka* and the *Śiṣyadhīvṛddhida* of Lalla adopt the Āryabhaṭan parameters. Govindasvāmī, (A.D. 800-850), commentator of the *Mahābhāskarīya,* and *Śaṅkaranārāyaṇa* (A.D. 825-900), commentator of the *Laghubhāskarīya,* both from Kerala, are prominent followers of the School of Āryabhaṭa.

The *Brahmasphuṭasiddhānta* of Brahmagupta started a school which was highly critical of the school of Āryabhaṭa. The *Sūryasiddhānta* (A.D. 650-950) started yet another school which is popular throughout North India, though it is little known in the South. The work is also extensively commented upon and has inspired several original works like the *Karaṇaprakāśa* of Brahmadeva (A.D. 1092). Muñjāla or Mañjula (A.D. 932), author of *Laghumānasa* is another prominent writer of the period. Sūryadeva Yajvan (b. 1191) hailed from Tamilnadu and is the author of extensive commentaries on the *Āryabhaṭīya* and *Laghumānasa* which are highly informative. Śrīpati (A.D. 1038) is the author of the extensive work *Siddhāntaśekhara* in 890 verses which has been commented upon by Pṛthūdaka. He has to his credit two more works, the *Gaṇitatilaka* and a calendrical work, *Dhruvamānasa-karaṇa* based on the *Laghumānasa.*

Bhāskara II (b. 1114) is, perhaps, the best known and prolific astronomer of this period. His *Līlāvatī* on Arithmetic, *Bījagaṇita* on Algebra and *Siddhāntaśiromaṇi* on astronomy, all equipped with his own commentary called *Vāsanā,* have been the mainstay of

mathematical and astronomical studies, especially north of the Deccan, from the time of their composition till the present day. *Karaṇakutūhala* or *Brahmatulya* is another elaborate work of Bhāskara, in 10 chapters, on calendrical astronomy, inspired by the *Brahmasphuṭasiddhānta* of Brahmagupta. Bhāskara's works have attracted more commentators than the works of any other Indian astronomer.

Development during the Second Phase: A.D. 1200-1800

The Second Phase of the medieval period has been much more productive than the First in the matter of the quantum of literature produced. It is generally presumed that there has been little progress in astronomical studies in India after the time of Bhāskara II. Thus, G. R. Kaye observes: 'After the time of Bhāskara (born 1114 A. D) no Indian mathematical work of historical value or interest is known'[1]. This view is echoed by practically all later writers. See, for instance, A. B. Keith, 'After Bhaskara, no progress has been recorded in Indian astronomy "[2]; A. A. Macdonell, "The last eminent Indian astronomer was Bhāskarācārya, born in A.D. 1114"[3]; Arka Somayaji, "Bhāskara is the last name in the field. Barring a number of commentators, no name worthy of mention is there in India subsequent to Bhāskara"[4]

Though even in the North there have been astute astronomers like Kamalākara (A.D. 1650), author of *Siddhāntatattvaviveka,* in the far-away South, in pockets like Kerala untouched by the political turmoil that rocked the North, there had been no interruption in the practice of the discipline, endangering the continuity of mathematical and astronomical thought. Hereditary families of scholars devoted themselves to the study of astronomy in peace, and records are available indicating unbroken lines of teachers and pupils extending over centuries. For instance, a Keralite palm-leaf record in Malayalam, deposited in the Oriental Institute, Baroda, coupled with the mention of the continuity of that line in a later work, shows a continuous chain of astronomers commencing from A.D. 1237 to 1846, i. e., more than 600 years.[5]

A survey of Kerala astronomers and their works made a few years back, by the present writer, had resulted in the identification of over 100 astronomers and 700 works pertaining to medieval times, as documented in *A Bibliography of Kerala and Kerala - based astronomy and astrology.*[6]

It has also been shown that working on the basic principles of algebra, geometry and limiting values, Kerala astronomers had produced significant results, which anticipate some of the later discoveries of European astronomers. A sampling of these 'anticipations' by Kerala astronomers, of Western discoveries might be noted here:

1. ***Reduction to the ecliptic*** **by Tycho Brahe (1546-1601):**

   Enunciated by Acyuta Piṣāraṭi (1550-1621), in his *Sphuṭanirṇaya* (4.2); simplified formula in his later (1583) work *Uparāgakriyākrama* (1.42); and both the formulae referred to in the *Rāśigolasphuṭānīti* (47)[7].

2. ***Irrationality of π*** **by Lambert (1671):**

   Categorically stated by Nīlakaṇṭha Somayājī (1444-1545) in his commentary on the *Āryabhaṭīya* (*Gaṇita*, 10, ed. pp. 41-42), in the words: *yena mānena mīyamāno vyāso niravayavaḥ syāt, tenaiva mānena mīyamānaḥ paridhiḥ punaḥ sāvayava eva syāt - - - - - - niravayavatvam tu kvāpi na labhyam iti bhāvaḥ* / ['Measuring with a unit which clears the diameter (of a circle) without remainder, (i.e., in full integers), the circumference, if measured by the same unit, will always have a remainder, (i.e., the result will never be a full integer),....... The sense is that there will always be a remainder'.] In other words π is an irrational number.

3. ***Leibnitz's Power series*** **for π (Gottfried Wilhelm Leibnitz, 1646-1716):**

   Implied in the verse *vyāse vāridhinihate*, etc. of Mādhava of Saṅgama-grāma (1360-1425), quoted by Śaṅkara Vāriyar (1500-60) in his com. *Kriyā-kramakarī* on the *Līlāvatī* of Bhāskara II, 199 (edn. p. 379).[8]

4. ***Gregory and Leibnitz's series* for the inverse tangent**

   (James Gregory, 1638-75; L., 1646-1716): Enunciated by Mādhava (1360-1425), and quoted by Śaṅkara Vāriyar (1500-60) in his com. *Kriyākramakarī* on the *Līlāvatī*, 199 (edn., pp. 385-86).[9]

5. ***Newton's Power series* for the sine and cosine: (Issac Newton: 1642-1727)**

   Implied in the verses *nihatya cāpavargeṇa* etc. by Mādhava (1360-1425), quoted by Śaṅkara Vāriyar (1500-60) in his com. In verse on Nīlakaṇṭha Somayājī's (1444-1545) *Tantrasaṅgraha*, 2. 15b-16a, com. Verses 431-35.[10]

6. **Newton-Gauss interpolation formula (up to the second order):**(N., 1642-1727):

   Enunciated by Govindasvāmī (c. 800-850) in his com. On the *Mahābhāskarīya* of Bhāskara I (4. 22).[11]

7. ***Taylor series approximations for sine and cosine functions*:**

   (Up to the second order of small quantities) (Brook Taylor, 1685-1730): Enunciated by Mādhava of Saṅgamagrāma (1350-1425), and quoted by Nīlakaṇṭha Somayājī (1444-1545) in his com. on the *Āryabhaṭīya, Gaṇita*, 12; enunciated in different words by Parameśvara of Vaṭaśśeri in his commentary (A.D. 1408) on the *Laghubhāskarīya* of Bhāskara I. [12]

8. ***Gregory's expansion of Third order Taylor series* approximation of the sine (A.D. 1668):**

   Equivalent formula for the first four terms, with a minor change, enunciated by Parameśvara (1360-1455) in his *Siddhāntadīpikā*, a super com. on the *Bhāṣya* of Govindasvāmin on the *Mahābhaskarīya* of Bhāskara I, (4.22; edn., p. 205, verses 14-16).[13]

9. ***Lhuiler's formula for the circum-radius of a cyclic quadrilateral* (A.D. 1782).**

   Enunciated by Parameśvara (1360-1455) in his com. on the *Līlāvatī* of Bhāskara II.[14]

10. Mean value theorem of differential calculus:

Parallel theorem promulgated by Parameśvara (1360-1455) in his *Siddhāntadīpikā. op. cit.* (edn., p. 205, verses 18-19).[15]

It is necessary to draw the attention of students of mathematics and astronomy to the fact that the works of Govindasvāmin, Śaṅkaranārāyaṇa, Mādhava, Parameśvara, Nīlakaṇṭha and Śaṅkara, to mention a few, are mines of mathematical ideas and application. The few correlations noticed above is a pointer to the massive work that remains to be done in the field and how essential that work is for a proper understanding and assessment of the development of mathematical thought in India.

Nature of Indian scientific tradition:

However, a full assessment of Indian astronomy poses some problems germane to Indian scientific tradition as a whole. Among other things, this tradition seems to have two notable characteristics, viz., astuteness and secretiveness. If astuteness enabled it to make effective use of observation, experimentation and intuition, secretiveness had the effect of obliterating, to a greater extent, the details of its development.

It may be noted that there is a sharp contrast between Western and Eastern scientific tradition, the former being rather extrovert and the latter introvert. Quite perceptible in the writings of early thinkers like Aristotle (384-22 B. C.), Euclid (300 B. C.) and Ptolemy (168 B. C.) the tradition has been continued by Arabic scholars like Al-Khwarizimi (A.D. 780-850) and Al-Biruni (A.D. 973-1050). In the case of post-reformation scientists of Europe, to whatever discipline they belonged, chemistry,. physics, mathematics, or astronomy, apart from their final documentation being logical and elucidative, even the pre-final writings and drafts of several of these scholars have been preserved. This tradition of the occident enables the understanding of the rationale of the problems tackled, besides giving an insight into the mental working of the individual scientists like Faraday, Newton, Kepler and Copernicus.

The matter is different in the case of India. Here, too, scientific advances, whether in the field of mathematics or astronomy, medicine or alchemy, mining or metallurgy, sculpture or architecture, should necessarily have been preceded by numerous experimentations, failures, alternate procedures, rationalizations and the like. However, these behind the curtain maneuvers have mostly remained unrecorded and lost on account of the characteristic secretiveness of Indian scientific tradition. The aphorismic style of writing, which developed in India from early days, required a thinker to depict his final results in the form of short formulae, leaving out the descriptions and the step-by-step derivation of those results. The practice percolated all disciplines, including grammar, the philosophies, medicine, mathematics and astronomy and had the effect of elbowing out of the depiction of the derivation or the explanation of the rationale of the formulae.

Commentators endeavoured rather to explain only the application of the formulae and not to look back, set out the data that should have been before the original author, visualize his mental working and deduce how the results were obtained. Thus, a commentator explaining a short prescription from a medical text would not go into the question of then numerous experiments and trials which the original author would have performed before he finalized the prescription. And, the commentary of a basic text on sculpture would rather explain the qualities of the kind of stone prescribed rather than describe the original author's experimentation of different stones and the reason for his choice of that particular stone.

In the case of disciplines involving material objects like medicine and sculpture, it might be easier to visualize and retrace the background processes. But it would be difficult to do so in the case of more abstruse disciplines like mathematics and astronomy which involve figure work calculations, presuppositions, hypotheses, innovations and even intuition.

Reconstruction of Astronomical Rationale

Under the circumstances, modern students of Hindu astronomy have attempted, naturally enough, to explain the rationale of Indian

astronomical procedures and formulae from the standpoint of Western processes and formulae. Indeed, substantial correlations, verifications and explanations have been effected in this matter by modern scholars of East and West. This method might enable one to ascertain the correctness of the said procedures and formulae, but the ascertainment of the actual manner in which the Indian astronomers arrived at these results, is another matter. As noticed earlier, ordinary commentaries are not of much help herein. While the *Yuktibhāṣā* in the Malayalam language had been known and the first part of it published[16], it has been the good fortune of the present writer to discover old palm-leaf manuscripts of certain other medieval works which set out the rationale of Indian mathematics and astronomy and also to publish some of these works critically. Among these may be mentioned the *Jyotirmīmāṃsā* of Nīlakaṇṭha Somayājī (A.D. 1444-1545)[17], *Sphuṭacandrāpti* of Mādhava (A.D. 1340-1430),[18] *Rāśigolasphuṭānīti* of Acyuta (1550-1621),[19] *Yuktidīpikā* (an elaborate exposition of the rationale of Hindu astronomy) being a commentary in verse on the *Tantrasaṅgraha* of Nīlakaṇṭha Somayājī[20] and *Kriyākramakarī* (an elaborate exposition of the rationale of Hindu mathematics), being a commentary in prose and verse on the *Līlāvatī* of Bhāskara II [21], both by Śaṅkara Vāriyar (A.D. 1500-60). The elaborate commentary on the *Āryabhaṭīya* by Nīlakaṇṭha Somayājī[22], is still another work containing much useful information in this direction.

A fact that is apparent from the above is that, despite the general reticence among Indian astronomers in the matter of recording the rationale of the thought, rules and practice of the discipline, there have been stray instances of astronomers who have taken the trouble to do so. More often than not, these astronomers take up specific points and not whole texts for rationalization. These short tracts, which do not form full-fledged works, are mostly found inscribed in end-folios of manuscripts and, on account of their amorphous nature, they are generally left out from being recorded by catalogues of manuscripts or are just indicated in such anomalous titles like *jyotiṣa-viṣaya* 'Miscellaneous astronomical tracts', thus blotting out their existence from the ken of the inquisitive users of the catalogues.

A number of astronomical manuals or *Karaṇa* texts, short or long, based on some main astronomical *Siddhānta* or other, have been composed during the medieval times. The authors of these *Karaṇa* texts adopt some suitable contemporary date as the epoch, specify fresh constants for calculation and often enunciate novel methods and processes all aimed at obtaining more and more accurate results of the astronomical phenomena. Since these texts do not generally indicate the source from which they take off or the reasons for their innovations, the latter will have to be identified and their rationales worked out. *Inter alia* the greater accuracy, if any, reached by them, will also have to be assessed.

The importance of the *Karaṇa* texts, rationalistic expositions and topical discussions, in the matter of assessing astronomical development in India cannot be over-estimated. It is in these works, and not in the full-fledged source books that one can hope to discover the results of the researches of contemporary astronomers. For a parallel from modern science, might be cited, the case of standard textbooks, which contain full-fledged depiction of accepted ideas, and contemporary research writings in periodicals which reflect current trends and new discoveries. It is therefore, essential that special attention is paid to the study of these type of texts. The different steps to be adopted towards such a study could be their identification, documentation, edition, translation, analysis, exposition in modern terms, correlation with current procedures, assessment, and, last but not least, application of the new ideas or trends of thought found therein for further advancement of the discipline.

Astronomical tradition of Kerala

Astronomers of all parts of the land can be found to have contributed in the production of the said type of rationalistic literature, but it is more so in pockets where astronomical investigations were carried on uninterrupted by political upheavals or other historic reasons. In Kerala, the land's end of India, with which the present writer is more familiar, such investigations had been a special characteristic right through the medieval period.

Dṛkkaraṇa, an astronomical manual composed in Malayalam verse in A.D. 1607-08[23] throws some interesting light in this direction on the advent of the *Āryabhaṭīya.* [24]

The *Parahita* system of Haridatta (A.D. 684)

The first major revision, in Kerala, of the astronomical constants enunciated by Āryabhaṭa was effected in A.D. 683-84 by a set of astronomers who had gathered for the twelve yearly *Māmāṅkam* (Mahāmagha) festival at the religio-educational center of Tirunavay in northern Kerala. The revised system, which came to be known as *Parahita-gaṇita,* has been enunciated by Haridatta in his *Grahacāranibandhana*[25] and *Mahāmārganibandhana*[26].

The *Dṛkkaraṇa* records this event in the following words:

Pinne- - - - - - avanītale. [27]

The promulgation of *Parahita,* being the revised *Āryabhaṭan* system, is recorded thus, in another Keralite astronomical work, the *Sadratnamālā* of Śaṅkara Varman (A.D. 1800-38)[28].

ācāryāryabhaṭa-praṇīta-karaṇam prāyas sphuṭam tat kalau
gotrottuṅga-mitābdake vyabhicaran brāhmādi-siddhāntake II
dṛgavaiṣamyavaśāt 'mahāsthala' - mite kalyabdake niścitaḥ I
saṃsk[illegible] vibudhair yataḥ parahitatvam teṣu vineṣvayam II
(*Prakaraṇa* 6, verses 1.3).

Ācārya Āryabhaṭa's astronomical treatise gave well-high accurate results in *Kali* year '*gotrottuṅga*' (3623=A.D. 522) while the (earlier astronomical) *Siddhāntas* ascribed to Brahma etc. were tending to be inaccurate.

When *Āryabhaṭan* results, too, tended to be inaccurate (as exemplified by their not tallying with observation), a correction was decided upon by astronomers (for all planets) other than the Sun. And the revised system was known as *Parahita,* because it was acceptable to all.

Dṛk System of Parameśvara (A.D. 1431)

The parameters of the *Parahita* system were revised by Parameśvara (A.D. 1360-1455) through his reputed work *Dṛggaṇita.*[29] The *Dṛkkaraṇa* describes its advent thus:

cirakālam kaḷiññappoḷ nīkkam vaḷare vannitu /
raṅgaśobhānu kalyabde kaścid vipravaras tadā /26//
paścimāmbodhi-tīrattu ninnu nokkīṭṭu vaccatu /27a//

When a long time had elapsed, there occurred substantial deviation (26a).

Then, (Parameśvara), a noble Brāhmaṇa, residing on the coast of the western ocean, revised it (i.e., the *Parahita* system) by means of (astronomical) observations, in the *Kali* year *raṅgaśobhānu* (4532=A.D. 1431) (26b-27a).

Revision by Nīlakaṇṭha (A.D. 1444-1545)

The *Dṛkkaraṇa* specifies the planetary revolutions depicted in the *Tantrasaṅgraha* as pertaining to '12 years later' than those of the previously mentioned revision, i.e., it refers to A.D. 1443-44, which is the year of birth of the author of the work, Nīlakaṇṭha Somayājī[30].

Cf: Dvādaśābdam kozhiññittu Tantrasaṅgraham ennatu //27b//

'Twelve years later (were determined the planetary parameters depicted in) the *Tantrasaṅgraha*'. (27b).

The *Dṛkkaraṇa* then records its own revision promulgated in A.D. 1607 *tasmin - - - - - - varunnatu.* [31]

This is followed, by the statement of the parameters, in the beginning of the next *pariccheda,* verses 1-6.

The *Sadratnamālā* also records this revision in the following verse:

pratyakṣataḥ parahite gaṇite 'pi bhedam
dṛṣṭvā kalau 'janasabha'-mita-vatsarānte /

rāddhāntite tu gaṇakair gaṇitāgame yad
dṛksāmyagamikaraṇādi tad atra vakṣye //VI. 43//

'Since differences between (values derived by) the *Parahita* computation and observation were noted, certain revisions were enunciated in the astronomical tradition by astronomers in *Kali* year (*janasabha*, 4708=A.D. 1607). I shall set out here those practices which tend to give results akin to those by observation.'

Then are given the new parameters and computational methods.

Literature from Kerala on Astronomical Rationale

As a result of intensive foraging through palm-leaf manuscripts deposited both in public and private libraries in Kerala, it has been possible for the present writer to discover, document and also prepare copies of about 200 works, short or long, many of them bearing dates, but mostly anonymous, including rationalistic tracts, *karaṇa* texts, topical discussions and the like[32].

A good part of the material contained in these works could be matter which is already known or repetitions and so considered as chaff, but a systematic study of these is bound to yield much useful gain and provide an insight as to how the discipline developed during the medieval times.

Desideratum

For an assessment of the development of astronomy in India, it is necessary that texts of the above-mentioned type be duly studied, analysed, expressed in terms of modern mathematics and the new 'insights' therein identified and expounded. And, the worth of the study as envisaged above lies in the application of the 'insights' provided by the 'ancient' lines of thinking, leading to 'modern discoveries'. In this respect, it can be asserted that medieval Indian mathematics and astronomy form potential and fecund fields for investigation.

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2. A. B. Keith, *A History of Indian Literature,* Oxford, 1929, p. 523.

3. A. A. Macdonell, *A History of Sanskrit Literature,* Indian Rep., Delhi, 1962, p. 370.

4. Arka Somayaji, *A Critical study of the ancient Hindu astronomy,* Dharwar, 1971, p. 3.

5. See the article *Direct lines of astronomical tradition in Kerala.*

6. Pub., Vishveshvaranand Inst., Hoshiarpur, 1972. For brief biographical details of these astronomers and their contribution, see K. V. Sarma, *A History of the Kerala School of Hindu astronomy,*Hosharpur, 1972, pp. 41-81.

7. For the demonstration see, K. V. Sarma, Introduction to his edn.of *Rāśigolasphuṭānīti* (rev. edn. Hoshiarpur, 1977).

8. For dem. See : C. T. Rajagopal and T. V. Vedamurthi Iyer, 'On the Hindu proof of Gregory's series', *Scripta Mathamatica,* 17 (1951) 65-74; K. Mukunda Marar and C. T. Rajagopal, '*On the quadrature of the circle*', *Jl. of the Bombay Br. of RAS,* (NS), 20 (1944) 65-82.

9. For dem. See; C. T. Rajagopal, T. V. Vedamurthi Iyer and K. Mukunda Marar, *ibid;* R. C. Gupta '*The Madhava-Gregory series*', Mathematics Education, 7.3 (Sept. 1973) 67-70.

10. For dem. See C. T. Rajagopal and A. Venkataraman, '*The sine and cosine power-series*', *in Hindu Mathematics, JRAS.* Bengal, (Sc.) 15 (1949) 1-10.

11. For dem. See: R. C. Gupta, '*Second order of interpolation in Indian Mathematics upto fifteenth century*', *Indian Jl. of History of Science* 4 (1969) 86-98, see pp. 91-92.

12. See R. C. Gupta, *Ibid*, pp. 92-96.

13. For dem. See, R. C. Gupta, '*An Indian form of third order, Taylor series approximation of the sine*', *Historica Mathematica, 1* (1974) 287-89.

14. For dem. See, T. A. Saraswathi, Development of mathematical ideas in India, Indian *Jl. of History of Science,* 4 (1969) 59-78.

15. For dem. See, R. C. Gupta, '*A Mean value type formula for inverse interpolation of the sine*', *Mathematics Education,* 10.1 (March, 1976) 17-20.

16. *Yuktibhāṣā,* (ed. with notes), by Rāma Varma (Maru) Thampuran and A. R. Akhilesvara Iyer, Mangalodayam, Trichur, Pt. I, 1949; Pt. II, Cr. Edn. with notes and translation in the name *Gaṇitayuktibhāṣā,* by K. V. Sarma, IIAS. Simla, 2007

17. Ed. by K. V. Sarma, Vishveshvaranand Inst., Hoshiarpur, 1977.

18. Ed. with translation, by K. V. Sarma, Hoshiarpur, 1973.

19. Ed. with translation, by K. V. Sarma, Hoshiarpur, 1977.

20. Cr. Ed. with Introduction, by K. V. Sarma, Hoshiarpur, 1977.

21. Cr. Ed. with Introduction, by K. V. Sarma, Hoshiarpur, 1975.

22. Ed. in the *TSS.*, Nos. 101, 111, 185, Trivandrum, 1930, 1931 & 1957.

23. This work, divided into ten sections called *paricchedas,* appears to have been written by Jyeṣṭhadeva, author of the astronomical treatise *Yuktibhāṣā* or *Gaṇitayuktibhāṣā.* The date of the composition of *Dṛkkaraṇa* is given in its concluding line thus: *Kolambe 'barhisunau' vihagagatiyatum nokki ittham camappu l'* Compute (as instructed and subtract the planetary positions for kollan year *barhisunu* (783) (=A.D. 1607-08).

24. See the article *The Scientific Spirit reflected in Indian Astronomy.*

25. Cr. Ed. by K. V. Sarma, with introduction K. S. Research Inst., Madras, 1954, See also K. V. Sarma, '*Parahita-gaṇitattiṇṭe mūlagrantham*', *Mātrubhūmi,* (Malayalam Weekly, Kozhikode), Oct.10, 1954.

26. This is apparently the full-fledged theoretical treatise of the *Parahita* system, while the *Grahacāranibandhana* is only its work manual. Manuscripts of the work are yet to come to light, but the work is known through a reference in *Grahacāranibandhana,* 2.44.

27. See the article *The Scientific Spirit reflected in Indian Astronomy.*

28. Edited (incomplete) in the Malayalam monthly *Kavanodayam,* (Kozhikode, Vol. 16, 1898). For Mss. See Nos. 8322-B. C. 2136 of the Kerala Uni. Mss. Library. Critical. Ed. by K.V. Sarma, INSC. New Delhi, 2001.

29. Cr. Ed. by K. V. Sarma, V.V.R. Inst., Hoshiarpur, 1963. The date of its composition is given towards the end of the work in the verse:

    evam Dṛggaṇitam śake triṣuviṣva-mite kṛtam
    paramādiśvarenai tat prāyo bhavati dṛksamam II.46II
    The *Dṛggaṇita* has, thus been composed in *śaka* 1353 (=A.D. 1431) by Parameśvara (lit. '*Īśvara*', prefixed by the word '*Parama*'). (The results obtained hereby will) tend to be the same as those by observations'.

    On the systems and the work, see the text and the Introduction to the above mentioned edition. See also, K. V. Sarma, '*Parameśvarācāryarute Dṛggaṇita*', *Mātrubhūmi,* (Malayalam Weekly, Kozhikode), Aug. 28, 1960, pp. 19-21.

30. On the date of Nīlakaṇṭha, see K. V. Sarma Cr. Edn. of *Siddhāntadarpaṇa of Nīlakaṇṭha Somayājī,* Hoshiarpur, 1976, Introduction, pp. xxv-xxvi.

31. See the article *The Scientific Spirit reflected in Indian Astronomy.*

32. For the documentation of some of these see, K.V. Sarma, *A Bibliography of Kerala and Kerala-based Astronomy and Astrology,* Hoshiarpur, 1972. Several works also have been discovered and identiified after the publication of the said Bibliography.

KERALA LITERATURE ON JYOTIṢA*

Introductory

The extensive Jyotiṣa literature produced in Kerala, in Sanskrit and in Malayalam, of which latter is the regional language of that part of India, comprise of original treatises, expositions of individual topics, commentaries on standard texts, computation manuals, minor tracts, single verses and manifold mnemonic tables. A good part of the shorter tracts and other secondary literature which do not form full-fledged works have been lost and what survives of this type of literature has to be looked for in flyleaves and folios of codices where such matter is generally found written. The definitive literature, too, has been affected considerably. The full extent of the literary activity in this line is not adequately known, much less recognised, for reasons of subject, script and language. However, an idea of this literary production could be judged from an examination of the surviving literature, a documented Bibliography of which is given in Chapter V, of the *History of the Kerala School of Hindu Astronomy*,[1] by the present writer. It may be noted that this Bibliography carries references to the manuscripts, editions and studies of about 450 works on astronomy, astrology and mathematics and details of about 100 authors and authorities.

2. Earlier Documentation

Some efforts have been made to take stock of the astronomical and allied literature of Kerala, though these attempts have hardly succeeded in giving any adequate idea of the extent of this literature. Thus, K.K. Raja's well-documented paper on '*Astronomy and mathematics in Kerala: An account of the literature*'[2] takes into its purview only some of the more prominent authors in these two disciplines numbering about 20 and their works numbering about 80, S.N. Sen's *Bibliography of Sanskrit works on Astronomy and mathematics*,[3] restricts itself to Sanskrit works and, there too, carries

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the documentation of just 13 Kerala authors and 47 works. The major histories of Kerala literature, viz., *Keralīya Sāhitya Charitram* by Ulloor S. Parameswara Aiyar,[4] *Keralīya Saṃskṛta Sāhitya Charitram* [5] and *Kerala Sāhitya Charitram: Carccayum Pūraṇavum*,[6] both by Vaṭakkumkur Rajaraja Varma and *Kerala bhāṣā Sāhitya Charitram* by R. Narayana Panikkar,[7] especially the first three, notice a much larger number of works and authors, though they, too, fail to do full justice to the subject. Nearly half of the literature on *Jyotiṣa* produced in the land does not find a mention in these volumes. Moreover, the accounts given in these histories are not documented and are, mostly, distributed in different volumes. Neither do these histories, except and of Ulloor, carry any index to help the reader in locating a work or an author dealt with therein. In the following pages, an attempt has been made to take notice of the broad trends and nature of the literature produced in this discipline. In order that the picture of Kerala *Jyotiṣa* might be presented in full, the account given below is not restricted to astronomy and mathematics but is made to include also the allied discipline of astrology, which constitutes the applied aspect of astronomy.

3. The Classical texts.

Some scholars have claimed that the foremost Indian astronomer Āryabhaṭa hailed from Kerala. Though this claim yet remains to be fully authenticated, the popularity of *Āryabhaṭīya* among Kerala astronomers is apparent from the profusion of manuscripts of that work recorded from this region[8] and from as many as eleven commentaries on it, in Sanskrit and Malayalam, written by Kerala astronomers, the more important among them being those composed by Sūryadeva Yajvan, Parameśvara of Vaṭaśreṇi, Nīlakaṇṭha Somayāji and Ghaṭīgopa.[9] Two other texts of the Āryabhaṭan school, viz., the *Laghubhāskarīya* and the *Mahābhāskarīya* of Bhāskara I, of which, too, most of the recorded manuscripts are from Kerala, have been equally popular in the land. There are seven Karalite commentaries on the former, by Śaṅkaranārāyaṇa, Sūryadeva Yajvan, Parameśvara, Udayadivākara and Śaṅkaran Nampūtiri, the others being anonymous. The latter work has five Keralite commentaries, including those by

Govindasvāmin, Sūryadeva Yajvan and Parameśvara. The other classical astronomical texts which were popular in Kerala are the *Sūryasiddhānta* which claims three Kerala commentaries, and the *Laghumānasa* of Muñjāla, which has at least four Kerala commentaries. The most popular text book on mathemathics has been the *Līlāvatī* of Bhāskara II, for which at least thirteen commentaries, besides several other works based on it, have been recorded. On the side of horary astrology, the *Horā* of *Bṛhajjātaka* of Varāhamihira enjoyed the greatest popularity; seventeen commentaries on this work by Kerala authors have been identified; besides, there are also several abridgements and adaptations of that work. On this subject, the *Jātakakarmapaddhati* of Śrīpati, which has three Kerala commentaries, has also been quite popular and in *Praśna* (Astrological enquiry), the pride of place goes to the *Praśna-ṣaṭpañcāśikā* of Pṛthuyaśas with two Kerala commentaries.

4. Major works on Astronomy

A number of original texts on astronomy, dealing with all the main topics of the subject, have been identified. Some of them, like the *Tantrasaṅgraha* of Nīlakaṇṭha Somayāji, the *Tantrasāra* of Nārāyaṇa of Peruvanam and the *Sadratnamālā* of Śaṅkara Varman, belong to the tantra type of treatises which take the beginning of the *Kali* era as the starting point for astronomical calculations. The bulk of the original texts are, however, of the *karaṇa* type, which use some convenient contemporary date as the epoch for starting the calculations enunciated by them, a device made of by modern astronomy as well. This date is so chosen that at the ending moment of that day, i.e., at the beginning (sunrise) of the next day, the Meaṇ Moon (*Candra*) and Mean Higher Apsis (*Candratuṅga*) are in the same position or very close to each other, so that the days accumulated up to the epoch (called *Khaṇḍa-dina* or *śodhya-dina*) could be subtracted in 'full' from the current *Kalidina*. The Mean positions of the Sun, Moon and other planets etc. are determined very accurately for the epoch and the readings so obtained are used as zero corrections for all computations for any date after the epoch. The *Grahacāranibandhana* of Haridatta, the basic *karaṇa* text of the *Parahita* system of Astronomy, however, uses the

date of Āryabhaṭa as the epoch, and the *Dṛggaṇita* of Parameśvara, the basic text of the *Dṛk* system, uses the beginning of *Kali* as its epoch. Some of the *karaṇa* texts are mere manuals giving rules for specific astronomic computations while some others like the *Karaṇapaddhati* of Putumana Somayāji, are fullfledged textbooks on the subject. Among the more important *karaṇa* texts may be mentioned the *Karaṇāmṛta* of Citrabhānu, which has three commentaries, the *Karaṇasāra* with commentary, possibly, by Śaṅkara Vāriyar pupil of Nīlakaṇṭha Somayājin, the anonymous *Karaṇadarpaṇa* with three commentaries, *Karaṇottama* of Acyuta Piṣāraṭi with two commentaries, of which one is by the author himself, the anonymous *Laghukālārpaṇa*, anonymous *Kriyāsaṅgraha* with two commentaries. Several *karaṇa* texts have the generic title *Pañcabodha*. Ten of them have been identified.

Most of these are anonymous and only three of the authors could be identified, they being Putumana Somayāji, Puruṣottama and Kṛṣṇadāsa. These *Pañcabodha*-s have been very popular with the almanac-makers of the land and most of these claim commentaries, as well. The *Pañcabodha*-s generally contain five sections dealing with five astronomical topics. The topics treated are not, however, always the same. Thus *Pañcabodha* III deals with *Vyatīpāta*, *Mauḍhya, Chāyā, Śṛṅgonnati* and *Grahaṇa*, while *Pañcabodha* II deals with *Tithi, Vāra, Nakṣatra, Yoga* and *Karaṇa*. Again, to deal with only five topics is not the rule in these works; the number of topics dealt with could be less or more than five. For instance, *Pañcabodha* V or *Pañcabodhaśataka* of Puruṣottama, in 100 verses, contains only two sections and *Pañcabodha* I is in ten sections, dealing with *Tithinakṣatra, Vākyadhruva, Madhyama, Sphuṭakriyā, Lāṭavaidhṛta, Mauḍhya, Sūryacchāyā, Somacchāyā, Śṛṅgonnati* and *Grahaṇa*. The *Bhadradīpagaṇita* of Iṭakramañceri Nampūtiri and the *Gaṇitasāra* or *Pañcabodha-gaṇitasāra* of Śaṅkaran Nampūtiri of Mahiṣamaṅgalam, both in Malayalam, are also comprehensive treatises.

Several of the *karaṇa* texts are smaller tracts devoted only to one or two topics like *Vyatīpāta, Vaidhṛti, Saṅkrama, Adhimāsa* etc. Three amongst these topics, viz., Computation of the Moon, Eclipses

and Shadow, seem to have attracted the special attention of Kerala astronomers and, as a result, a large number of manuals have come to be composed on these subjects. Some of these works attempt also at evolving new processes, offer new corrections and give the rationale to the procedures adopted. Most of these texts are anonymous.

5. Computation of the Moon

The fact that the calculation of the exact *tithi* (lunar day) and *nakṣatra* (asterism) at any moment depends upon the accurate knowledge of the Moon at that moment and that all the three, viz., *tithi, nakṣatra* and Moon, are always required for the fixation of social and religious functions, in horoscopy and in the computation of eclipses etc. is enough to explain the importance given to the computation of the Moon. But the fast motion of the Moon, amounting to about 13 degrees a day, and the consequent quick change of its position during the same day required special consideration in its correct computation. A good number of *karaṇa* texts, devoted specifically for the computation of the Moon, have, therefore, been composed. Among the more important manuals of this type may be mentioned the *candra-sphuṭagaṇita* with a commentary and a super-commentary; *candra-sūrya-sphuṭa,-gaṇita, Candra-sphuṭādi-gaṇita, Śuddha-candra-kriyā-gaṇita, Śrāddha-candrādi-gaṇita* and *Sūkṣmacandra-sphuṭādi-gaṇita*, all anonymous.

6. *Veṇvāroha* method for the Moon

Of all heavenly bodies, the Moon has not only the fastest motion, but also the maximum changes in its velocity during the same day. Therefore, the computation of the Moon at some intermediate time during the day, if calculated on the basis of its true position and motion at sunrise and sunset, as advocated in some *Pañcabodha* texts, would not give accurate results. An ingenious but facile method for the determination of the Moon at any time of the day with high accuracy has been evolved by the 14th century Kerala astronomer Mādhava of Saṅgamagrāma in his work called *Veṇvāroha*. He has also enunciated accurate- moon-mnemonics, correct to the seconds,

for being used in the *Veṇvāroha* method. His method seems to have caught the fancy also of later astronomers who have extended the method further to yield still more accurate results. At least four later works of this genre have been identified, they being *Candra-sphuṭāpti, Veṇvārohakriyā* and *Dṛg-veṇvārohakriyā* all anonymous, and *Veṇvārohāṣṭaka* of Putumana Somayāji.

7. Computation of Eclipses

A branch of astronomy in which intense investigations have been made by Kerala astronomers refers to the computation of eclipses. The phenomenon of eclipses seems to have been exploited fully towards verifying calculations, instituting corrections and devising new methodologies. Parameśvara of *Dṛggaṇita* fame is known to have scanned the heavens for full fiftyfive years and to have recorded information about a large number of eclipses which occurred during the period. Apart from minor tracts, a number of texts on the computation of eclipses have come down. These include three works having the common title *Uparāgakriyākrama*, the first by Nārāyaṇa with commentary, the second by Acyuta Piṣāraṭi, with two commentaries, and a third, which is anonymous; an *Uparāgaviṃśati* with commentary; *Grahaṇamaṇḍana* by Parameśvara; six anonymous works with the common title *Grahaṇa-gaṇita*, five works under the title *Grahaṇāṣṭaka*, one of which is by Parameśvara and the other anonymous; and the three works, *Candra-grahagaṇita, Candra-sūryoparāga-gaṇita* and *Sūrya-grahaṇa-gaṇita*, all anonymous. Two works on eclipses which deserve special mention are the *Grahaṇa-nyāya-dīpikā* of Parameśvara, *Grahaṇa-grantha (Grahaṇanirṇaya)* of Nīlakaṇṭha Somayāji, which is an elaborate disquisition on the tradition and rationale of computing eclipses.

8. Computation of the shadow

Computation of the positions of the Sun and the Moon from the Shadow (*Chāyā*) cast by them and vice versa had practical utility in the social and religious life of the people of mediaeval times. Besides calculations made on the basis of the *Śaṅku* (Gnomon), intrinsic

calculations involving the *Mahācchāyā* (Great Shadow or Sine Zenith distance) and the *Mahāśaṅku* (Great gnomon or Sine Altitude) had been developed in this behalf. Some of the *Pañcabodha*-s and other *karaṇa* texts mentioned above have sections devoted to Shadow computation. Besides these, several independent works devoted solely to this subject have also been produced. Among the works of this category may be mentioned six different works, all entitled *Candracchāyā-gaṇita*, one of these being by Parameśvara, another by Nīlakaṇṭha Somayāji and the others anonymous; four of these works have also commentaries. Other works on the subject include the *Chāyāgaṇita, Chāyāgraha-gaṇita*, *Chāyādigaṇita* and three different works having the common title *Sūryachāyādi-gaṇita*. Piṣāraṭi, too has written a succinct work on the subject, entitled *Chāyāṣṭakam*.

9. Long range almanacs

In the matter of preparing annual almanacs, while the general trend in Kerala, as elsewhere, has been to prepare them for one year at a time, efforts had been made to prepare long-range almanacs covering long periods. It has been recorded that Mādhava of Saṅgamagrāma compiled an *Agaṇita-pañcāṅga*[10] that is, probably, the same as referred to in the *Karaṇapaddhati* (IV. 14, 16, 18) and preserved in the Kerala University Oriental Research Institute under the title *Agaṇitagrahacāra*. Śaṅkaran Nampūtiri of Mahiṣamaṅgalam is credited with a Register of *Muhūrta*-s for 1000 years.[11] The *Agaṇita* of Nalleppalli Subrahmaṇya Śāstri enunciates methods for the facile computation of the planets for a thousand years.

10. Astronomical rationale

An extremely significant class of astronomical treatises from Kerala refers to disquisitions on the rationale of astronomical formulae and procedures. Short expositions of this nature occur in commentarial literature, especially in the commentaries of Parameśvara, Nīlakaṇṭha Somayāji and Nārāyaṇa, author of *Kriyākarmakarī* on Com. *Līlāvatī*. Single or groups of verses and short tracts pertaining to the expositions of specific points or procedures are often found inscribed, without

indication of source or author, in end-leaves of astronomical codices; these go mostly unnoticed or ignored by cataloguers of manuscripts. It would, indeed, be highly worthwhile to record, study and analyse these passages with a view to see if some of them contain anything important. In this connection, the discovery of some full-fledged treatises devoted to the exposition of astronomical theories and processes ought to be highly interesting to scholars and historians of mathematics. These texts, which, generally, have the words *yukti* or *nyāya* 'rationale' attached to their titles, explain, interpret and discuss the formulae used and procedures followed in the topics, which they deal with. Among works of this nature may be mentioned the *Grahaṇa-nyāya-dīpikā* on the computation of eclipses and *Vākyakaraṇa* on the formulation of astronomical mnemonics, both by Parameśvara of Vaṭaśreṇi, the *Yuktibhāṣā* or *Gaṇita-yuktibhāṣā* by Jyeṣṭhadeva, the *Nyāyaratna* by Putumana Somayāji, the *Gaṇita-yuktayaḥ* by an anonymous '*Bhāradvāja brahman*' and the *Rāśigola-sphuṭānīti* on 'Reduction to the ecliptic' by Acyuta Piṣāraṭi. The *Sundararāja-praśnottara* by Nīlakaṇṭha Somayāji, in which he gives his solutions to certain problems of astronomical theory and practice raised by a contemporary astronomer Sundararāja of the Tamil country, also belongs to this category of works.

11. Practical astronomy

Astronomy being a practical science, progress in that discipline in incumbant less on computational skill than on practical observation. Several works including the *Goladīpikā* I of Parameśvara and the *Bhadradīpa* of Iṭakramañceri Nampūtiri contain sections on the construction and use of the armillary sphere. The commentaries of Parameśvara and Nīlakaṇṭha Somayāji carry references to their lifelong astronomical observations. By far the most interesting treatise in this line is the *Grahaparīkṣākrama* of Nīlakaṇṭha Somayāji, in about two hundred verses. There is also a detailed Malayalam commentary on this work. An equally interesting, though late work is *Nāzhikamaṇiyuṭe yukti*, which is a detailed exposition of the working of the pendulum clock.

12. Revision of astronomical constants

As indicated earlier, the composers of *karaṇa* texts generally introduced in their works contemporary epochs. Sometimes they also enuciated corrections to the astronomical constants, and to the sine tables which they incorporated in their works. A work solely devoted to the enunciation of corrected constants is the *Siddhāntadarpaṇa* of Nīlakaṇṭha Somayāji, wherein he has set out the number of revolutions of the planets, and their higher apses, ascending nodes, maximum latitudes, velocities etc., as investigated and verified by him. He has also written an elaborate commentary on this work. Then again, there exist a large number of manuscripts which form collections of sine tables and other mnemonics and are catalogued in libraries under generic titles like *Jyāḥ*, *Jyotiṣavākyāni* etc. on account of their not being full-fledged and independent works these collections are potential sources of additions and novelties to the well-known mnemonics and, so, deserve to be examined from this point of view.

13. Mathematics

The *Līlāvatī* of Bhāskara II, with thirteen Kerala commentaries, has remained, as indicated earlier, the most popular textbook on general mathematics. Among indigenous works, some of the astronomical treatises like *Yuktibhāṣā, Bhadradīpa* etc. deal with general mathematics in some of their sections. An interesting summary of the general mathematical processes is contained in an anonymous work entitled *Ekaviṃśatipraśnakrama*. Other works solely devoted to the treatment of mathematics are *Kaṇakkatikāram*, with commentary, two works having the same title *Kaṇakkusāram*, one in prose and the other in verse, both with commentaries, *Kaṇakkucodyam* and *Kaṇakkuśāstram*, all anonymous.

14. Horary astrology

While the classical texts on *Jātaka* used in Kerala were the *Bṛhajjātaka* of Varāhamihira and the *Jātakakarmapaddhati* of Śrīpati, the most popular indigenous text on the subject was the *Jātakapaddhati* of Parameśvara of Vaṭaśreṇī, which has as many as

eight commentaries and *Jātakādeśamārga* of Putumana Somayāji. From among other works which enjoyed varied popularity, may be mentioned the *Jātakakarma* and *Jātakasāra* of Śaṅkaran Nampūtiri of Mahiṣamaṅgalam, the *Jātakanītimārga* and *Jātakasārasaṅgraha* by Āḷvāñceri Tāmprākkal and anonymous *Jātakodaya.*

15. Auspicious times (*Muhūrta*)

Practically all the texts popular in Kerala, enunciating the fixation of auspicious times (*muhūrtas*), for the numerous religious and social ceremonies, are of indigenous origin. The *Muhūrtadarśana* of Vidyāmādhava of Nīlamana near Gokarṇa, with six commentaries, and the *Muhūrtaratna* of Govinda Bhaṭṭatiri of Talakkulattūr, with its commentary by Parameśvara of Vaṭaśreṇī, are the early texts of this category. But, by far the most popular works on the subject are two *Muhūrtapadavī*-s written by two brothers of the Māttūr family in Kochin, whose names, have, hitherto, remained unknown, but can be identified as Puruṣottama and Subrahmaṇya. The popularity of these two *Muhūrtapadavī*-s can be judged from the profusion of manuscripts of these works available and the seven commentaries composed on them.[12]

16. Astrological query (*Praśna*)

The branch of astrology called *Praśna* has been very popular in Kerala where many a new technique and practice has been evolved. The classical work on the subject which was popular in the land was the *Praśnaṣaṭpañcāśikā* of Pṛthuyaśas, son of Varāhamihira, which claims two good Kerala commentaries. There has, however, been substantial literary production in consonance with the high popularity of its practice. Here too, several treatises comprehending all aspects of *Praśna* and many others which specialised items have come to be composed. The most important work of the former category is the *Praśnamārga* by a Nampūtiri of the Panakkāṭṭu family, possibly named Parameśvara. Numerous manuscripts of this work and of the four commentaries on it have been recorded. A good number of later works have been based on it or take it as the Chief authority. Other full-fledged works on *Praśna* include three treatises with the identical title

Praśnasāra, one by Śaṅkara, the second by a Somayāji of Bhūtanāthapura and the third by Mādhava of Īñcakkāḷva family, two works of the name *Praśnānuṣṭhānapaddhati*, both anonymous, *Praśnāmṛta* of Śrīkumāra, *Praśnāyana* of Puruṣottama with auto-commentary, *Praśnamālā*, possibly by Śaṅkaraṇ Nampūtiri of Mahiṣamaṅgalam, with commentary, two works entitled *Praśnarīti*, one by Dāmodaran Nampūtiri of Maṅgalaśśeri and the other by Iṭakkāṭṭu Kṛkkaṇiyāl and three different works of the name *Praśnalakṣaṇa*, all anonymous. Among works dealing with individual subjects, there are a large number devoted to topics like *Aṣṭamaṅgala, Āyus, Āyudha, Roga* etc.

17. Natural astrology

Of classical texts on natural astrology, the *Bṛhatsaṃhitā* of Varāhamihira and *Parāśarasaṃhitā,* attributed to sage Parāśara were generally known, besides *Lampāka* by Padmanābha, a later work well known in the whole of South India. Among works on natural astrology produced in Kerala, a mention might be made of *Sāmudrikasāra* of Śaṅkara, with two commentaries, two anonymous *Sāmudrikalakṣaṇa*-s and *Raṇadīpikā* by Kumāra. The last-mentioned work which , in eight chapters, deals in detail with the preparation for and conduct of war, is particularly significant. Some works deal with individual topics like *Bhūparīkṣā*, *Rekhāśāstra* etc. and some others with special types of prognostication like *Naraceṣṭita, Pakṣiśāstra* etc.

18. Malayalam versions of Sanskrit texts

It is interesting to note that almost all *Jyotiṣa* works in Sanskrit have one or more commentaries or renderings in Malayalam, produced, obviously, with a view to facilitating their study among the non-Sanskrit knowing public. This is a feature found in certain other regions of India as well. The Malayalam versions are generally called the *Bhāṣā* of the works concerned. Often the author of the original work prepares this *Bhāṣā* himself and at other times, others. There have also been adaptations and abridgements of Sanskrit works. A very instructive instance of this trend is found in the works of an Āḷvāñceri Tamprākkal

of the last century who, in a series of works, adapted a number of important Sanskrit texts and also provided the Malayalam renderings for these adaptations. Thus, his *Phalasārasamuccaya*, in three parts, forms, in its Part I called *Jātakabhāga*, an adaptation of the *Horā* of Varāhamihira and the *Sārāvalī* of Kalyāṇa Varman, in Part II called *Praśnabhāga*, an adaptation of the *Praśnamārga*, of Panakkāṭṭu Nampūtiri, and in Part III entitled *Muhūrtabhāga*, of the *Muhūrtadarśana* of Vidyāmadhava. In fact, of the ten works credited to this author, five, viz., *Jyotiśśāstrasaṅgraha, Saṅgrahasādhanakriyā, Jātaka-sārasaṅgraha, Jātakanītimārga* and *Phalasārasamuccaya*, are in Sanskrit and the other five, form the *Bhāṣā* of these five works.

19. *Kerala-Jyotiṣa* outside Kera la

That some of the characteristic innovations, extensions and practices evolved in Kerala in the discipline of *Jyotiṣa,* especially in its astrological aspect, have travelled beyond its borders and become current in certain other parts of India is but natural. It is again natural that, as these theories and practices grew popular in those regions, local treaties came to be composed incorporating the new ideas. Most of these treatises are distinguished by the term 'Kerala' tacked on to their titles.[13] However, what seems highly significant in this matter is the variety and profusion of the works that have been composed in this manner. About 80 works of this nature have been identified in the different Manuscripts Libraries.[14] Their non-Kerala origin has been determined from the following indications: (1) Clear mention of alien authorship, (2) the addition of the term 'Kerala' to the title, (3) the popularity of the works in other parts of India, while they are virtually unknown in Kerala, (4) the availability of manuscripts of these works only in non-Kerala scripts and (5) the general absence of the works in Kerala. While the bulk of these works are anonymous, some are apocryphal texts attributed to ancient sages or said to be parts of larger *Tantra*-s and *Saṃhitā*-s. Only a few of these are known under the names of their real authors. The disciplines of *Jātaka* and *Praśna* claim the largest number of these works, the former about 20 and the latter about 35.

In horoscopy, some of th tters in *Akṣaracintāmaṇi* section of *Keralamata* ascribed to Śiva, *Keralapraśna* or *Keralīya-jñāna* and *Akṣarakevalīpraśna*, both anonymous; on the basis of the throw of the dice in *Kerala-praśnāvalī* of Garga and two anonymous works *Keralī-praśnavicāra* and *Keralīya-śakunāvalī*; and on the basis of arecanuts in *Keralapraśna* (anonymous, Mithila III. 180). Of works on natural astrology, a mention might be made of *Keralayātrā* on setting out on a journey, and *Keralī* on the throbbing of the limbs and on dreams, both anonymous, *Keralī-śakuna*, on omens, attributed to Vyāsa.

The desideratum:

The non-Kerala works on Kerala *Jyotiṣa* mentioned of above, demonstrate how the specialities of a discipline as evolved in one region of India have been transmitted to the other parts of the country and how they have been accepted, preserved and propagated in those parts under the label of their original place of origin. It is well to remember here that it is but natural that during their transmission and propagation through the centuries, some of the original ideas might have undergone slight modifications. It is also possible that some new or local ideas have come to be incorporated in these works and are being paraded as Keralite views. It would be extremely instructive to investigate this phenomenon fully. Comparative studies between the non Keralite works and allied Keralite works could show how far the former represent the original views. The textual or other sources from Kerala, if any, of the individual non-Keralite works have to be identified. It would also be interesting to examine why these works are almost always unknown in Kerala, the land to which the ideas expressed therein are supposed to belong.

NOTES AND REFERENCES:

1. Pub., Vishveshvaranand Institute, Hoshiarpur, 1972.
2. *Adyar Library Bulletion,* 27 (1963) 118-67.
3. Part I: *Manuscripts, Texts, Translations and Studies*, National Institute of Sciences of India, New Delhi-1, 1966.

4. Pub., University of Kerala, Trivandrum, 5 vols., 1953-57. *Keralīya Samskṛta Sāhitya Charitam,*

5. Pub., Vol. I, Kamalalaya Book Depot, Trivandrum, M.E. 1113 (A.D. 1938) Vols. II-VI, Mangalodayam, Trichur, M.E. 1122-40 (A.D. 1947-65).

6. Pub., 2 vols., Mangalodaya, Trichur, 1967-69. both by Vaṭakkumkūr Rajaraja Varma, and *Kerala Bhāshā Sāhitya Charitram* by R. Narayana Panikkar.

7. Pub., 7 Vols., Vidyavilasini Book Depot, Trivandrum,? 1951.

8. Of about 120 manuscripts of Āryabhaṭīya recorded in the *New Catalogus Catalogorum of Sanskrit and allied works and authors*, Vol. II, (Madras, 1966), p. 171, as many as 85 are from Kerala,

9. For details of the manuscripts, editions, extent, dates and available studies on these works, as also of other works that might be referred to below see Ch. IV, '*Bibliography of Kerala works on Astronomy etc.*', in the *History of the Kerala school of Hindu astronomy*, by the present author, *op. cit.*

10. See the article *Direct lines of astronomical tradition in Kerala*'.

11. Ulloor, *Kerala Sahitya Charitram*, Vol. II, Trivandrum, 1954, p.272.

12. To cite but one instance, the Kerala Oriental Res. Inst. and Mss. Library holds in its collectsions not less than 103 of these manuscripts as recorded in their Catalogoues.

13. This phenomenon is found in varying degree, also in the case of certain other disciplines like *Tantra, Śrauta, Dharma* and *Mantraśāstra*.

14. For a classified and documented list of the manuscripts of these non-Kerala works, see Appendix to the present writer's *History of the Kerala school of Hindu Astronomy*, Hoshiarpur, 1972.

CORRECTIONS IN INDIAN ASTRONOMY: PRINCIPLES AND METHODS IN MEDIEVAL KERALA*

Nature of early Indian texts

Early Indian texts on technology and science are generally couched in dogmatic terms. The authors of these texts were more interested in setting out the results of their researches, on the background of and interspersed with traditional knowledge, than to explain the rationale of their statements. Nor did the authors take the trouble to distinguish their individual contributions from what each of them had derived from their predecessors. This impersonal way of writing, coupled with the tradition of setting out things as briefly as possible in the form of aphorisms or hemistiches, has practically blurred the picture of the rational development of science and technology in India. Even in commentaries of these texts, the exposition of rationale is more an exception than the rule.

Texts on Mathematics and Astronomy

Presentation of texts in the disciplines of mathematics and astronomy follows but the traditional pattern. Even when an author specifies that he is setting out things logically *(yuktyā)* and by observation *(dṛṣṭyā),* when it comes to actual depiction of the matter, he might give neither the methods of his observations nor the rationale of his computations. To cite an instance, Parameśvara (1360-1455) the author of *Dṛggaṇita*[1] (1451-52), asserts at the beginning of the work.

दृश्यन्ते विहगाः - - - - - - - - - - मया [2] ।

However, in the body of the text *Dṛggaṇita,* the author presents only the formulae and methods for the different computations, without giving any rationale whatsoever. Here, a modern student is at a loss to know the actual advance which the author had made over his predecessors, or the rationale of his corrections or the methods by which he had arrived at those corrections. This situation should, be disheartening to a student of the history of Indian astronomy.

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Jyotirmīmāṃsā of Nīlakaṇṭha Somayāji

An insight into the mental working of the medieval Indian astronomer and of the methods adopted by him in developing the discipline have now become available in a recently discovered unique work entitled *Jyotirmīmāṃsā* ('Investigations and astronomical theories') by the Kerala astronomer Nīlakaṇṭha Somayāji (1444-1545). This work, of which only a single palmleaf manuscript is available in a miscellaneous codex in the Mahārājā's palace collection, Trivandrum was discovered and identified by the present writer and has recently been edited critically by him and published through the Vishveshvaranand Institute, of the Punjab University (Hoshiarpur, 1977). The manuscript is unfortunately incomplete but the available portion is extremely significant in that it provides substantial information on the progressive views of the astronomers and on the methods adopted by them to develop the discipline.[3]

Logical approach to astronomy

It is highly interesting that, at the very outset of the work, as it is available to us, Nīlakaṇṭha aims to establish, in detail, that astronomy is an experimental science and that expressions like 'divine instruction' (*Īśvaropadeśa*), 'early authorities' (*āptavacana)* and inspiration (*ātma-pratibhāsa*) are all inclusive and not exclusive. As far as astronomy is concerned, 'observational exactitude' (*dṛṣṭi-sāmya)* is supreme and efforts should be concentrated towards corrections and computations that would give results matching observation. Thus, he says at one place:

"ननु तपोभिः प्रसन्नो ब्रह्मा आर्यभटस्य भगणपरिध्यादिकं ग्रहगणनसाधनभूतं संख्याविशेषमुपदिदेश। तदुपदिष्टं पुनरार्यभटः सर्वं यथोपदिष्टमेव दशभिर्गीतिभिर्निबबन्ध इति केचिन्मन्यन्ते। तस्य कुतः परीक्षणम्, ब्रह्मणः सर्वज्ञत्वात् अवितथत्वनिश्चयात् इति चेत् - मन्द ! मैवम्। देवताप्रसादो मतिवैमल्यहेतुरेव। न च पुनः ब्रह्मा आदित्यो वा स्वयमेवागत्य उपदिशेत्।"

Some might argue like this: "God Brahmā was pleased by the penance of Āryabhaṭa and so imparted to him knowledge about the astronomical parameters useful for planetary computation. And,

Āryabhaṭa set into *gīti* verses the knowledge imparted to him. Hence there is no necessity for any further experimentation, for God Brahmā is omniscient and infalliable." To this the reply is; "Fool, it is not so. Divine favour merely cleanses the intellect. Never can God Brahmā or the Sun appear before one in person and impart instruction."

Nīlakaṇṭha emphasizes, on the other hand, that the discipline of astronomy can be kept alive and accurate only by continued observation of the skies and effecting necessary revision, periodically, in computation. Quoting an authority he observes:

गणितोन्नीतस्य चन्द्रादेः देशविशेषान्वयस्य प्रत्यक्षेण संवादः ततो निश्चितान्वयस्य परस्य गणितर्लिङ्गोपदेशः, ततस्तयाप्तोपदेशावगतान्वयस्य अनुमानं, संवादः, परस्मै चोपदेशः इति। (edn., p. 3)

Thus the method consists in the correlation of the computed Moon, etc. with actual observation at a particular place, the revision of the computation on the basis of such correlation, logical inference there from being handed down as tradition, it being again correlated (with observation in due course and again revised as necessary) and transmitted further down to others - this is how astronomical tradition is continuously revised and handed down and hence its authoritativeness.

Referring to earlier schools of astronomy and their inaccuracy to-day, Nīlakaṇṭha observes:

पञ्चसिद्धान्तास्तावत् क्वचित्काले प्रमाणमेव इत्यवगन्तव्यम्। अपि च यः सिद्धान्तो दर्शनाविसंवादी भवति सोऽन्वेषणीयः। दर्शनसंवादश्च तदानीन्तनैः परीक्षकैर्ग्रहणादौ विज्ञातव्यः। ये पुनरन्यथा, प्राक्तनसिद्धान्तस्य भेदे सति यन्त्रैः परीक्ष्य ग्रहाणां भगणादिसंख्यां ज्ञात्वा अभिनवसिद्धान्तः प्रणेय इत्यर्थात्, तत् न इहलोकेऽसहनीयाः परलोकेऽदण्डनीयाश्च । (edn., p. 6)

'One has to accept that each of the Five *Siddhānta*s (summarized in the *Pañcasiddhāntaṭīkā* of Varāhamihira, viz., *Brāhma, Vāsiṣṭha, Saura, Pauliśa* and *Romaka*), had been correct some time or the other (though they might not be so now). Therefore, one has to look for a system, which would tally with observation now. The said tallying has to be verified by contemporary astronomers by observation. When the two differ from one another, i.e., when an earlier system does not

agree (with observation), experiments have to be conducted with instruments, and revolution-numbers of the planets calculated there from and a new school of astronomy has to be started. Nobody will be censured for this in this world nor punished in the next'.

Nīlakaṇṭha's methodology for revision

From amongst the different astronomical phenomena, well defined eclipses being the most amenable for the verification of astronomical systems and effecting corrections thereto, their utilization for the purpose is stressed by Nīlakaṇṭha, mentioning the method for this, he says:

अथ सिद्धान्तदीपिकायामुदाहृतानि ग्रहणानि परीक्ष्यमाणेन गण्यानि। अन्यानि वा ऐतिह्यसिद्धानि स्ववंश्यैरुपदिष्टानि गण्यन्ताम्। एतैः प्रत्यक्षावगतैश्च अनागतग्रहणं निर्णीय वक्तव्यम्। जनपदान्तरजान् उपरागान् तद्देशान्तराक्षादिभिः गणयित्वा रवीन्दुतुङ्गपातान् विज्ञाय अतीतमनागतं स्वदेशजं ग्रहणं स्वदेशान्तराक्षाभ्यां विज्ञातैस्तैरेव ग्रहोच्चपातैर्गणयित्वा निर्णेयाः।

(edn., pp. 31-32).

'The eclipses illustrated in the *Siddhāntadīpikā*[4] might be computed (in all their details) by the experimenter. Even so might be computed other eclipses handed down by tradition in one's own school. In the light of these and other eclipses actually observed by oneself, future eclipses should be computed and forecasts or, eclipses occurring in other parts of the country should be computed using the latitude, longitude etc. of that part of the country, and with that as the basis, the True Sun, Moon and Node (at the relevant times) ascertained. Then, from the Sun, Moon and Node, ascertained (as above), past and future eclipses at one's own place shall be computed, using the local latitude.[5]

Nīlakaṇṭha follows up the above instruction with the details of a number of eclipses observed and recorded by Parameśvara in the *Siddhāntadīpikā.* (edn. pp. 32-35). He then indicates the procedure for verification thus:

सिद्धान्तशेखराद्युक्तमध्यमेभ्यः परमेश्वरोक्तानां नूतनत्वाद् अस्य दृष्टिसाम्यं स्यात्। तस्मात् सिद्धान्तदीपिकोदाहृतानि अस्माभिः (नीलकण्ठेन) दृष्टानि च तत्तदवसरे वक्ष्यमाणानि परमेश्वरोक्तप्रकाशेण अर्कादिमध्यमान्यानीय श्रीपत्युक्तप्रकारेण स्फुटीकृत्य कालक्रियागोलपादोक्ताभिः अस्माभिर्व्याख्याताभिः युक्तिभिः सिद्धैः क्रियाविशेषैश्च गण्यन्ताम्। (edn., p. 35).

'The computation of the Mean planets having been enunciated by Parameśvara later than Śrīpati, the former will tally (better) with observation. Therefore, in the case of the eclipses enumerated by Parameśvara, those observed by me (Nīlakaṇṭha) and by others that might be mentioned hereafter the Mean Sun, etc. shall be computed as directed by Parameśvara. Their true positions shall (however) be computed according to Śrīpati's method. 'The eclipses should then be computed duly making use of the methods derived from the rationales enunciated by me (in my *Bhāṣya)* on the *Kālakriyā* and *Golapāda*-s of the *Āryabhaṭīya*).

The above-said instructions are then illustrated by Nīlakaṇṭha by a practical example in the case of a solar eclipse that occurred on *Kali* day 16, 43, 524. (edn. pp. 35-36).

In the further portion of the *Jyotirmīmāṃsā,* Nīlakaṇṭha touches upon the revision of the Procession of the Equinoxes, true motion, position, of planets, etc. But, in spite of the incompleteness of the work, as available now, the message is clear. Astronomy was a live science in India till late medieval times, at least in certain parts of the country, like Kerala, where the rationale of the calculations involved were known and corrections and emendations to earlier methods were continued to be done, with a view to seeing that computed results tallied with observed astronomical phenomena.[6]

NOTES AND REFERENCES:

1. *Dṛgganita*, ed. K. V. Sarma, V.V.R.I., Hoshiarpur, 1963.
2. For detailed ref. see article '*The Scientific Spirit reflected in Indian Astronomy*'.
3. For the identification of the work, see Introduction to the edition, pp. ix-xiv, and for details about the author, *see* pp. xxvii-xxxviii.
4. The reference is to *Siddhāntadīpikā,* the super-commentary by Nīlakaṇṭha's grand-teacher Parameśvara on Govindasvāmin's *Bhāṣya* on the *Mahābhāskarīya* of Bhāskara I, under verse 5.77 Edn. by T.S.K. Sastri, Madras, 1957, pp. 329-332.

5. The following are some of the medieval Keralite works which expound the rationale of mathematics and astronomy.

   a. *Yuktibhāṣā* (in Malayalam) by Jyeṣṭhadeva (1500-1610), Pt. I., ed. with notes by Rama Varma Maru Thampuran and A. R. Akhileshwara Iyer, Mangalodayam, Trichur, 1949.

   b. Pt. II. with trans. and notes, published by K.V. Sarma, Indian Inst. of Advanced Studies, Shimla, 2006-07.

   c. Com. *Yuktiprakāśikā* by Śaṅkara (1500-60) on the *Tantrasaṅgraha* of Nīlakaṇṭha Somayāji, ed. by K. V. Sarma, Vishveshvaranand Institute, Hoshiarpur, 1977.

   d. Com. *Kriyākramakarī* by Śaṅkara (1500-60) on the *Līlāvatī* of Bhāskara II, ed. by K. V. Sarma, Hoshiarpur, 1975.

   e. Super Com. *Siddhāntadīpikā* by Parameśvara (1390-1455) on the *Bhāṣya* by Govindasvāmin on the *Mahābhāskarīya* of Bhāskara I, ed. by T.S.K. Sastri, Madras, 1957.

   f. *Rāśigolasphuṭānīti* acc. to Acyuta (1550-1621), ed. by K. V. Sarma, Hoshiarpur, 1977.

   g. *Sphuṭacandrāpti* of Mādhava of Saṅgama-grāma (1360-1425), ed. by K. V. Sarma, Hoshiarpur, 1973.

   h. *Gaṇitayuktayaḥ* (A series of Rationales of Hindu Astronomy), ed. by K. V. Sarma, Hoshiarpur, 1979.

   i. Also see the article *Kerala Literature on Jyotiṣa*.

6. For more ref. see also the article *Jyotirmīmāṃsā of Nīlakaṇṭha Somayāji*.

DATE OF MĀDHAVA- A LITTLE KNOWN INDIAN ASTRONOMER*

Āryabhaṭa's school of Indian astronomy (499 A.D.) had much following in the South of India, especially in Kerala where the system has been assiduously studied and developed and followed to this day. Significant improvements and corrections came to be made in a number of works in this school written by a long line of Kerala scholars. One of the more important of these last mentioned writers is Mādhava of Saṅgama grāma and author of a work called *Veṇvāroha*, who, however, does not find mention in the printed records of Indian mathematics and astronomy. In fact, even in his own home province his contributions have yet to be fully evaluated.

Mādhava is frequently quoted as an authority by Kerala astronomers.[1] Two of his significant contributions to mathematics known from these quotations are his enunciation of formulae for the accurate determination of the circumference of a circle and the value of π by the method of indeterminate series, a method which was re-discovered in Europe nearly three hundred years later.[2] by James Gregory (1638-75) and Gothfreid Wilhelm Leibnitz (1646-1716), and the formula for the Sine of the sum of two angles, Sine (A+B) = Sine A, Cos B+ Cos A. Sine B. Thus in his commentary *Kriyākramakarī* on the *Līlāvatī*, section of circles (II.40), Nārāyaṇa discussing the various views on the determination of the circumference of a circle says :

यद्येवमतिसूक्ष्मः परिधिः कथमानेतुं शक्यत इति चेद् अत्राह माधवः - - - - । इतोऽपि लघुतरपरिध्यानयनोपायः अमुनैवोक्तम् । यथा-

व्यासे वारिधिनिहते रूपहते व्याससागराभिहते ।
त्रिशरादि विषमसंख्याभक्तमृणं स्वं पृथक् क्रमात् कुर्यात् ।।
- -
लब्धः परिधिः सूक्ष्मो बहुकृत्वो हरणतोऽतिसूक्ष्मः स्यात् । इति ।

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*Quarterly Journal of Mythic Society, Bangalore, Vol. XLIX. no. 3. 1958.

This would give the value-

$\pi/4 = 1 - 1/3 + 1/5 - 1/7 + \ldots\ldots + 1/n\text{-}2 - 1/n + 1/n\text{+}2$ which is the same basic series attributed to Gregory and Leibnitz[3].

Quite often when Mādhava is mentioned, his name is prefixed with a title *Golavid* (expert on spherics). Thus Acyuta Piṣāraṭi in the opening verse of his *Sphuṭanirṇaya* paying homage to his predecessors in the field, says वन्दे गोलविदश्च माधवमुखान् , and the commentary on the work explains, माधवो वेण्वारोहादीनां कर्ता Nīlakaṇṭha Somayāji says in his commentary on *Āryabhaṭīya* - अत एव गोलविदा माधवेन विक्षेपवतां स्फुटापक्रमानयने गणितविशेषः प्रदर्शितः (Mss. trav. Uni. Mss. Library , T. 298, p. 186); तच्च सङ्गमग्रामजेन गोलतत्त्वविदां माधवेन प्रदर्शितम् (*ibid.* p. 138.). It would seem from such references that Mādhava was especially proficient in spherical astronomy. A Manuscript of Mādhava's *Veṇvāroha*[4] contains in continuation of that work, another work called *Golavāda* and it is possible that the *Golavāda* too is a work of Mādhava and that it was this work that got him the title *Golavid.*

The only work of Mādhava hitherto known as *Veṇvāroha*[5], an astronomical manual which enunciates an ingenious method for the accurate calculation of the longitude of the moon. Herein the author deals elaborately with the preparation of a table using which the longitudes of the moon could be read out at short intervals of one and a half *nāḍikā*-s each, the same table being valid for a cycle of 248 days.

Towards the end of *Veṇvāroha*, the author mentions another work of his, a set of astronomical *Vākyas* (short formulae expressing specific numbers in the *Kaṭapāyādi* notation) commencing with the *vākya* 'शीलं राज्ञः श्रिये' *cf.*

'शीलं राज्ञः श्रिये' कृत्वा प्राक् पुनर्येन निर्मितम् ।
विलिप्तिकादिकं वाक्यजातं तेनेयमीरिता ।। (verse no. 73)

This work, which I could identify and trace to four Manuscripts,[6] is a set of 248 *vākyas*, giving the daily motion of the moon correct to the second, for accurate calculations of the moon and especially in the preparation of his *Veṇvāroha* table.

No other full-fledged work of Mādhava is known so far. However, in later works we meet with numerous quotations from Mādhava comprising all aspects of Mathematics and astronomy and it is quite probable that he has written other works from which these quotations are taken. The statement of the commentator of the *Sphuṭanirṇaya,* previously referred to, माधवो वेण्वारोहादीनां कर्ता, also supports this view. An anonymous commentary on a fragmentary astronomical work[7] has the verse-

'लम्बाप्ते लम्बकर्णः स्यात् त्रिज्यापरपराहते ' ।
इत्युक्तत्वाद् गोलविदा लग्नप्रकरणेऽपि च ।।

The expression *Golavidā* here would seem to refer to a specific author, Mādhava being the only author from Kerala thus styled might be the author of this work. A work *Lagnaprakaraṇa* in eight chapters is known[8] and the above is the eighth verse in Ch. V, thereof.

That Mādhava belonged to Saṅgamagrāma, a village. The name Saṅgama, is testified by all authors quoting him by prefixing his name with the expression *Saṅgamagrāmajaḥ*. Saṅgamagrāma in Kerala is a place called Iriññālakkuṭa in Cochin, famous for the temple of Saṅgameśvara (Bharata). In verse 13 of his *Veṇvāroha,* Mādhava gives also his family-title.

बकुळाधिष्ठितत्वेन विहारो यो विशेष्यते ।
गृहनामनि सोऽयं स्यान्निजनामनि माधवः ।।

The Malayalam commentary on this work gives the local form of the word *Iraññi ninna paḷḷi*; cf. "*Bakulam = Iraññi , vihāram = paḷḷi. Iraññi ninna paḷḷi enna illa-p-per.*" This house exists even now in that place, though the present descendants have failed to preserve their scholarly tradition.

It is possible to fix the date of Mādhava from the epoch he gives in the *Veṇvāroha*. For the calculation of the mean Sun, it gives the epoch of दीननम्रानुशास्य (15,02,008) *Kali* days (i.e. 1010 A.D.) and आदिकूर्म (5180) cycles of the moon, corresponding to 390 years, the two together giving the date 1400 A.D. as the date of the work. This date of the author is also supported by other evidences. Thus Nīlakaṇṭha

Somayāji who lived and studied at the house of Paramaeśvara, says about the latter: परमेश्वरस्तु... माधवादिभ्यो गोलविद्भ्यो गणितगोलयुक्तीरपि बाल्य एव सम्यग् गृहीत्वा[9], etc. Parameśvara wrote his *Dṛgganita* in 1430 A.D. (*Śaka* 1353) which date is mentioned at the end of that work 'एवं दृग्गणितं शाके त्रीषु-विश्व-मिते कृतम्' It is quite possible that Mādhava wrote his work thirty years before that of his disciple. We may, therefore, consider him to have lived between 1350 and 1410 A.D.

NOTES AND REFERENCES:

1. *Cf.* Nīlakaṇṭha Somayāji, in his several works; Nārāyaṇa in his Commentary on the Līlāvatī; and Śaṅkara in his Commentary on *Tantrasaṅgraha*, etc.
2. On Mādhava's date 1350-1410, see further.
3. It may also be mentioned here that Mādhava enunciates further corrections to this basic series, an investigation into which is beyond the scope of this article, and should form a separate study.
4. Belonging to the Elamkunnappuzha Naṭakkal Kovilakam, Ernakulam.
5. This work with the Malayalam commentary of Acyuta Piṣāraṭi is being issued serially in the *Ravi Varma Granthāvali*, Vol. II-III (1955-56), Sanskrit College, Trippunithura, by the author, and published later as no.7, *Sri Ravivarma Skt. Ser.*, Sanskrit College, Trippunithura,1956.
6. This has been given astronomy an appendix to the above edition.
7. Mss. Madras Mal. D. 339, p. 66.
8. For Mss. see Kerala Uni. Mss. Library, 414-B, L. 1360-C.
9. *Āryabhaṭīya Bhāṣya* Mss. Kerala Uni. Mss. T.298, p. 258.

THE GRAHAṆĀṢṬAKA OF PARAMEŚVARA:*

A Short Manual on Eclipses : Edition and Translation

The *Grahaṇāṣṭaka* presented here in a critical edition is one of the shorter works of Parameśvara who holds an honoured place among medieval astronomers of Kerala. That Parameśvara wrote a *Grahaṇāṣṭaka* which has been suggested before,[1] but the work has not hitherto been indentified[2] nor brought to the notice of scholars.

Manuscript Material : The present edition is based on the following five palmleaf manuscripts, all in Malayalam script, of which one, designated A, originally belonged to the family of the author himself:

A. Ms. No. 475-K of the Kerala University Mss. Library, Trivandrum, an old and crumbling manuscript containing several astronomical works, of which some are Parameśvara's. The codex is over 400 years old, its date of transcription, A.D. 1551, being given in *Kaṭapayādi* notation by the *Kalidina* chronogram सेव्यो दुग्धाब्धितल्पः (16,99,817) at the end of the first work in the codex[3]. The scribe and original owner of the Ms. is mentioned as Nīlakaṇṭha of the *Vaṭaśreṇī* (or *Vaṭaśśeri*) family to which our author too belonged.[4] The text preserved herein is almost pure.

B. Ms. No. C. 166-E (modern copy in No. T. 179-B) of the above Library. This is also a codex of astronomical works. It shows lacunae at places and the text contained is often erroneous.

C. Ms. No. 339-C in the private collection of the Vayaskara Illam, Kottayam, one of the eight families of traditional physicians of Kerala. This Ms. is much worm eaten but the text preserved in it is generally free from errors.

D. A. Ms. From the family collection of Elamprakkoṭṭu Mana Āḍhyan Nampūtiri, Eravoor, Trippunithura, Cochin. The Ms. originally

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*JOR. Madras, 28. 1960. As this has not been printed as an independent book, this has been reproduced here also.

belonged to Kūṭallūr Meleṭattu Mana as noted on the flyleaf. A codex containing ten astronomical works, it has passed through the hands of a revisor and contains a very correct text.

E. Ms. No. L.1248 B-1, of the Kerala University Mss. Library, in a codex containing a number of astronomical works. The text is written on ff. 20b-22a in a set of folios containing miscellaneous astronomical bits, the whole set of leaves catalogued anomalously as *Khaṇḍajyādi.* The text preserved contains many scribal errors.

Parameśvara, the Author

Parameśvara, author of *Grahaṇāṣṭaka,* came of the *Bhārgava gotra* and *Āśvalāyana Sūtra* and was a resident of the village of Ālattūr in the Ponani Taluk of South Malabar. His own house was situated on the northern bank of *Niḷā* or Bhāratappuzha river where it joins the sea, which fact he mentions in several of his works : *cf.* निळाब्ध्योः सङ्गमात् सौम्ये स्थितेन (col. verse to commentary on the *Sūryasiddhānta*).[5] He also gives its terrestrial latitude and longitude:

Cf. समरेखायाः पश्चादष्टादशयोजनान्तरे ग्रामे।
स्वर-कृत-षट्-तुलिताक्षे (end of *Goladīpikā* II)

"18 *yojana*s to the west of the (Ujjain) meridian and at a Sine latitude of 647 (or 10^0-51') from the equator." Parameśvara's parentage is not known, but he mentions his teacher Rudra in several of his works. That Parameśvara studied also under a Mādhava and a Nārāyaṇa is attested by his *praśiṣya* Nīlakaṇṭha Somayāji, cf. परमेश्वरस्तु रुद्र - परमेश्वरात्मजनारायण-माधवादिभ्यो गोलविद्भ्यो गणित-गोलयुक्तीरपि बाल्य एव सम्यग् गृहित्वा (*Āryabhaṭīya-Bhāṣya,* on *Gola* 48, *TSS* 185, p. 154). That his grandfather was the pupil of a Govinda[6], author of *Muhūrtaratna,* is stated by Parameśvara himself in his commentary on that work; cf.

गोविन्दपूज्यपादेन कृपासंसिक्तचेतसा।
मुहूर्तागमदुग्धाब्धेर्मुहूर्तमणिरुद्धृतः। ।
तस्मिंस्तच्छिष्यपौत्रेण कियांश्चित् परमादिना।
भावो विव्रियते स्वल्पमीश्वरेण यथाश्रुतम्।।

This Govinda is referred to by Parameśvara in his *Ācārasaṅgraha* also;

cf. पितुः पितुर्मे गुरुरग्रजन्मा गोविन्दनामा भुवि विश्रुतोऽयम्।
तेनोदितो यो गुरुपंक्तितो मां प्राप्तः स आचार इह प्रदिष्टः।।

Date of Parameśvara

Parameśvara himself gives the date of completion of two of his works. Thus he wrote the *Dṛgganita* in A.D. 1431; *cf.*

एवं दृग्गणितं शाके त्री-षु-विश्व (1353) मिते कृतम्।

And his *Goḷadīpikā*, in A.D. 1443; *cf.*

* * * शाकेऽक्ष-षट्-त्रि-चन्द्र (1365) मिते।
परमेश्वरनाम्नेयं वदनभुवा गोलदीपिका रचिता।।

Since Parameśvara is known to have carried on his investigations for 55 years before he established his new system and wrote the *Dṛgganita* in 1431, and since Nīlakaṇṭha Somayāji (born A.D. 1443) speaks of himself being instructed by Parameśvara[7], our author might be taken to have lived between 1365 and 1460.

Works of Parameśvara

Parameśvara is reputed as the foremost astronomer of Kerala, his chief service to the science being the revision of the *Parahita*[8] system of astronomy prevalent in the land and founding the *Dṛgganita* system in order to make the results of astronomical calculation accord with actual observation. Besides presenting the fundamentals of the new system in a work called *Dṛgganita*, Parameśvara has also written several original treatises on the various aspects of astronomy. On the theories and conceptions of spherical astronomy he wrote two *Goladīpikās*[9] and a commentary on one of them; the short *Grahaṇāṣṭaka* edited here and the longer *Grahaṇamaṇḍana*[10] and the (*Grahaṇa*) *Nyāyadīpikā*[11] on lunar and solar eclipses; *Vākyakaraṇa*[12] on the method of derivation of the several astronomical tables used for calculations; and *Vyatīpātāṣṭaka-vṛtti*[13] (in verse) on *Lāṭa* and *Vaidhṛta*. Parameśvara wrote also erudite commentaries on almost all ancient astronomical

texts held as authoritative in Kerala: *Bhaṭadīpikā* on the *Āryabhaṭīya*[14], *Pārameśvarī* on the *Laghubhāskarīya* of Bhāskara I,[15] *Karmadīpikā* on the *Mahābhāskarīya* of the same author[16], *Siddhāntadīpikā* on Govindasvāmin's *Bhāṣya* on the *Mahābhāskarīya*[17], *Pārameśvarī* on the *Lagumānasa* of *Muñjāla,*[18] *Vivaraṇa* on the *Sūryasiddhānta*,[19] and on the *Līlāvatī* of Bhāskara II.[20] Parameśvara has contributed also to the astrological side of Jyotiṣa through his original works, the *Ācārasaṅgraha*[21] and *Jātakapaddhati*[22] and commentaries on *Muhūrtaratna* of Govinda,[23] *Jātakapaddhati* of Śrīpati[24] and the *Praśnaṣaṭpañcāśikā* of Pṛthuyaśas.[25] Manuscripts of three other works, *Muhūrtāṣṭaka-dīpikā, Vākyadīpikā* and *Bhādīpikā* which Parameśvara enumerates among his works at the end of his commentary on the *Mahābhāskarīya*[26] are yet to be discovered. There are also certain other works, which are likely to be Parameśvara's but which lack confirmative evidence on his authorship. The above enumeration of Parameśvara's writings is ample testimony to his erudition and the vast contribution he has made in the fields of Indian astronomy and astrology.

Grahaṇāṣṭaka

The *Grahaṇāṣṭaka* edited here is a succinct manual on the calculation of the eclipses. Since much matter had to be compressed in the eight verses, the work is necessarily terse and technical. It should also be noted that the object of the author is primarily to enunciate certain principles in the calculations and to give revised measurements and tables as contrasted with the older system which it takes for granted. It does not, therefore, treat of the processes of calculation exhaustively nor in their sequential order; this the author does in the *Grahaṇamaṇḍana*. The translation added to this edition has been made lucid with explanatory notes in brackets and the text is properly punctuated to make the meaning easily intelligible.

I am especially thankful to Sri T. S. Kuppanna Sastri, who helped me in the edition and translation of this difficult work.

I am indebted to the Honorary Director, University Manuscripts Library, Trivandrum, Sri N. S. Moos of the Vayaskara Illam, Kottayam, and the Adhyan Namputirippad, Elamprakkottu Mana, Eravoor, Trippunithura, for the manuscripts used for this edition and I take this opportunity to express my gratitude to them.

NOTES AND REFERENCES:

1. Ullor states that a *Grahaṇāṣṭaka* might be a work of Parameśvara (*Kerala Sahitya Caritram,* II. 100), but makes a wrong identification when he gives as a *Grahaṇāṣṭaka* - quotation a verse which really occursin another work of Parameśvara (II 104). Vaṭakkumkūr Rājāraja Varmain his account of Parameśvara (*History of Sanskrit Literature in Kerala,* I.378 ff.) does not mention this work at all.

2. In fact there are several *Grahaṇāṣṭakas.* For Mss. of some of the other *Grahaṇāṣṭakas* see Kerala Uni. Mss.: C. 173-K (Beg. नाळोऽसौ गानसम्पत्); 5113-F (Beg. सूर्येन्द्वोर्ग्रहणं स्फुटं गणयितुं); 5867. ff. 160-63 (Beg. पातोनात् स्वमृदुस्फुटात्)

3. *Cf.* fol. 7b.

4. *Cf.* fol. 99a: वटश्रेण्याख्येन नीलकण्ठेन लिखितमिदं स्वीयं च।

5. See also ending verses of Parameśvara's *Goladīpikā,* II, *Mahābhāskarīya-bhāṣya-vyākhyā* and the introductory verses of his commentary on the *Līlāvatī.*

6. This Govinda is often wrongly identified with Govnidasvāmin, commentator of the *Mahābhāskarīya* (eg. Ulloor, *Kerala Sāhitya Caritram,* II 96, 102). It may be noted that Govindasvāmin is a very early author who followed closely upon Bhāskara I (6th cent. A.D.) and is cited by *Śaṅkaranārāyaṇa* (A.D. 869) in his *Laghubhāskarīyavivaraṇa* (*TSS.* 162, pp. 1, 19, 55, 95) and hence is different from this Govinda.

7. *Cf. Āryabhaṭīya-bhāṣya,* on *Golapāda*, 48 (*TSS* 185, p. 139).

8. The basic text of this system, the *Grahacāranibandhana* of Haridatta, has been edited by the present writer through the Kuppuswami Sastri Research Institute, Madras, 1954.

9. It may be noted that Parameśvara has written two *Goladīpikās* which are essentially different though treating the same subject. *Goladīpikā* I has been edited in the *Trivandrum Sanskrit Series,* No. 49, and *Goladīpikā* II with Parameśvara's own commentary edited, by the present writer for the Adyar Library, Madras, 1957.

10. For Mss. see Kerala Uni. 788-B, L.1248-G, C. 166-D.

11. This is a hitherto unknown work of Parameśvara, a fragmentary Ms. of which is available in the last folios of the Kerala Uni. Ms. 762. It begins:

    नमः सवित्रे ग्रहणे क्रियते **न्यायदीपिका**।
    कर्मक्रमस्तु तत्र प्राङ् **मण्डनादौ** प्रदर्शितः।।

    And ends:

    परमादीश्वरेणैषा श्लोकानां **न्यायदीपिका**।
    कृता पञ्चयुताशीत्या सेव्यतां गणकोत्तमैः।।

12. This too is a hitherto unknown work of Parameśvara. It begins:

    पूज्यपादस्य रुद्रस्य शिष्योऽयं **परमेश्वरः**।
    करोति **वाक्यकरणं** वाक्यावयवसिद्धये।।

    A Ms. of it is preserved in the Kerala Uni. Mss. Library, No. C.133-A.

13. Ms. Kerala Uni. 788-D.

14. Ed. H. Kern, Leiden, 1874.

15. Ed. *Anandasrama Skt. Series,* 128, Poona, 1946.

16. Ed. *ibid.* 126, Poona, 1945.

17. Critically edited in the *Madras Govt. Or. Series,* 130, by T. S. Kuppanna Sastri, 1957.

18. Ed. *Anandasrama Skt. Series,* 123, Poona, 1944.

19. Mss.: Madras Or. Mss. Library, No. R. 3730, Kerala Uni. 8358-J.

20. Mss.: Kerala Uni. 10614-B; Madras R. 338, R. 5160.

21. Mss.: Trivandrum Palace, 867, 868, 869; Kerala Uni., 1055-D.

22. Mss.: Kerala Uni., C.1052-B., C.2478-E.

23. Ms.: Kerala Uni., T. 144.

24. Ms.: Kerala Uni., C. M. 665.

25. Mss. Kerala Uni. 5963, 12235, T. 612.

26. *Cf.* concluding verse of the commentary:

    मुहूर्ताष्टक-सिद्धान्त-वाक्य-भा-न्याय-कर्मणाम् ।
    दीपिकां गोल-भटयोश्चाकरोत् परमेश्वरः ॥

परमेश्वराचार्यकृतं ग्रहणाष्टकम्

नत्वा भास्करमश्वत्थग्रामजः परमेश्वरः।
स्थूलोपरागगणितं कथयत्यष्टकेन च [a]।।

3623

भास्वत्तुङ्गौ प्रसिद्धौ [b]; शशिनि कलिगताब्दाद् गुणाश्व्यङ्गरामै-

46 11 7

र्हीनाल्लिप्ता निधेयाः स्वरकृतविहृताः; ताः शिवघ्नाः स्वराप्ताः।

5 1

शुद्धे राहौ च देया दिनकरशशिनोर्बाण-भूघ्ने[c] तु भुक्ती[d]

9 25

बिम्बे गो-तत्त्वभक्ते, गतिरथ[e] शशिनः पञ्चलिप्ताविहीना।। (१)

6

अङ्गघ्नाऽऽप्तार्कगत्या मितिरिह तमसः प्राग्विलग्नं त्रिभोनं
दृक्क्षेपं, पर्वणोऽन्ते विवरत इह याः सूर्य-दृक्क्षेपयोर्ज्याः।

62 120 169 207

भार्धोक्ता लम्बसंज्ञाः क्रतुनि नरकिनां [f] धूर्तकः सन्नखानां

231 240

योगीन्द्रो[g] निर्भरज्ञः[h] षडिति विघटिकाः स्वर्णमूनेऽधिकेऽर्के[i]।। (२)

10

ताभ्यो दिग्भिर्हतांशैः सहित-विरहितात् सायनाद् बाहुभूज्या

12 21 24

ग्राह्या दृक्क्षेपलग्नात्, प्रिय -कर -वरं[j] इत्यंशकास्तेऽपमाख्याः।

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a This introductory verse is available only in ms. E. bB. प्रवृद्धौ
c E. gap for one letter with त्तै. d B. भक्तो e A. गतिरिह
f. E. नरकत ? ब्युक्तकृत् g. A.D.E. योगीन्द्रं
h. A. ज्ञेः D. ज्ञैः E. ज्ञं i. B. C. मूनाधिकेऽर्के J. B.C. वरं h. A. ज्ञेः D. ज्ञैः E. ज्ञं i.
B. C. मूनाधिकेऽर्के J. B.C. वरं

100

जूकाजाद् याम्य[k]सौम्यास्त्वथ खखविधवोद्धाहताक्षाङ्गुलोना[l]

20

भूयश्चाक्षाङ्गुलघ्ना गगनयमहृता[m] याम्यगाश्चाक्षभागा:[n] (३)

युक्ता विश्लेषिता वा समविषमदिशस्तेऽपमाक्षाख्यभागा

3

नत्यंशा: स्यु:; तदूनाद् गुणमितभवनाद् या तु जीवाऽऽपमाख्या।

24

लम्बार्थे सा गुण:[o] स्यात्, कृतयमलमितस्तत्र हारो, गुणघ्नं[p]

हाराप्तं लम्बनं स्यात् स्फुटमिति गदितं[q] पूर्वलम्बस्य च ज्या।। (४)

20 38 51 56 56 47 28 6

नेत्रे[r] जालं कृशानां तृण-तम-सवनं दूर-तानीति माना [s]

नाड्यर्धेऽष्टौ विनाड्यो गुणकविनिहता हारभक्ता: स्फुटा: स्यु:।

तद्युक्तं स्फष्टलम्बं[t] स्फुटतरमुदितं; तद्धनर्णं च पर्वण्यस्मिन्

भानोर्हि मध्यं; पुनरिह पलभा-मध्यदृक्क्षेपसिद्धात्।। (५)

नत्यंशाल्लम्बजीवा दिनकरशशिनोर्भुक्तिभेदांशनिघ्ना [u]

भक्ता षष्ट्या नति: स्याद् ; अहिरहित विधोर्मध्यजाद्[v] दो: कलाघ्ना:।

149

गत्यंशा: क्षिप्तिलिप्ता नवनृपतिहृतायाम्यसौम्यास्तुलाजात्;

नत्या: क्षेपस्य चैक्यं समदिशि, विवरं त्वन्यथा,[w] क्षिप्तिरर्के।। (६)

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k.सौम्या अथ l. C. य m. A. हृतं n. C. मार्गा:
o. C. गुणं E.. म्गुणा p. A.E.. गुणघ्नो q. B. स्फुटमपि विहतं C.स्फुटनमपि वि ____(? दितं) E. स्फुटमथ विहिता: r A.. क्षेत्रे s Mss. Corrupt. A. दूरनानान B. दूरता नानीति C. दूरता नानिति D. दूरनानीनि E. दूरनानानिती t B. लम्ब: u E. भेदान्तरघ्ना v A.D. जा w D. चान्यथा

2 6 12 20

ऐक्यार्धात् क्षेपहीनाद् दिनकरशशिनोः श्री-स्तन-ग्राम्य-नारी-

32 55 93 125 148 160

रागे शुद्धे विनाड्यः शिशु-गाल शरकृद् देवकी-नास्तिकानि।[x]

स्थित्यर्धं [y] ; तद्युतोनं त्वविकृतमिह यत् पर्व तस्मिन् कृते स्वे [z]

लम्बेऽन्त्याद्यौ [a] च कालौ सवितु; रथ विधोः क्षिप्तिरिन्दूद्भवैव [b]।। (७)

मध्यं पर्वाहिविध्वोर्युतिदलनिचयात् क्षेपहीनाद् विशुद्धे

1 5 13 28 56 2 4 6 8 9

यो-मे-गोपी-दुरज्ञे-तम इति र-भ-ते दु[c]-ग्ध-नाडीस्थितिः स्यात्।

8 16

वस्व-ष्ट्यंशाववाच्यौ;[d] युतिदलमुभयोः क्षेपहीनं ग्रहांशः;[e]

पश्चात् प्राक्स्पर्शमोक्षौ किल सवितुरतः[f] क्षेपवद्धान्यथेन्दोः।। (८)

मन्दबुद्धिहितायैवं रचितं ग्रहणाष्टकम्।

परमेश्वरनाम्नैतत्; प्रायो भवति दृक्समम्[g] ।। (९)

।। इति ग्रहणाष्टकं समाप्तम्।।

---

x A. नांस्तकानि B. नांस्त्रिकानि C. नास्त्रिकानि D. नास्तकानि y E. स्थिथ्यंशं z A.D. कृते द्वे C. कृतेस्स्वे a B. C. E. न्ताद्योः b E. भवेव c B. C द d B. त्त्यौ e A. नग्रहांशः E. ग्रहांश्च f B. रितः g B. C. E. Omit this verse.

TRANSLATION OF GRAHAṆĀṢṬAKA

Maṅgalācaraṇa

Having paid obeisance to the Sun, Parameśvara hailing from *Aśvatthagrāma* enunciates a rough calculation of the eclipses in an Octad (of verses).

(Correction to the Longitudes)

1. भास्वत् .... देया. The Sun and the Moon's Higher Apses are to be as they are. Deduct 3623 from the *Kali* years and divide the reminder by 46; the resulting minutes are to be added to the Moon. This multiplied by 11 and divided by 7 is to be added to *Rāhu* (i. e. the final *Rāhu*), after the deduction (from 12 signs has been made).

(The Angular Diameters)

1. दिनकर..... 2. तमसः... The daily motion of the Sun multiplied by 5 and divided by 9 is the angular diameter of the Sun. The daily motion of the Moon divided by 25 is the angular diameter of the Moon. The daily motion of the Moon *minus* 5', multiplied by 6 and divided by the daily, motion of the Sun is the diameter of the Shadow.

(The Nonagesimal)

2. प्राग्विलग्नं...दृक्क्षेपं. The Orient ecliptic-point *minus* 3 *Rāśis* is the *Dṛkkṣepa-lagna* or Nonagesimal.

(A certain set of 'Special Sines')

2. पर्वणोऽन्ते...मुनेऽधिकेऽर्के. The sine of the difference in longitude, between the Sun and the Nonagesimal called the sine for *Lamba*, at the time of conjunction (is to be found); the following set of *Vināḍis*, 6 in number, are the sines of the difference in longitude for every difference in half Sign (*Viz.* 15^0, 30^0, 45^0, 60^0, 75^0 and 90^0): 62, 120, 169, 207, 231 and 240. These are plus (i. e., to be added) if the Sun is less (than the Nonagesimal), and minus if greater.

(The Declination of the corrected Nonagesimal)

3. ताभ्यो....सौम्यास्तु. Divide by 10 the 'sine' found above. The results are degrees. Add or subtract the degrees (as directed above) to or from the *Sāyana* Nonagesimal (i. e. the Nonagesimal as reckoned from the *First Point of* Aries). Take the *Bhujā* of this and find its corresponding sine declination given hereunder for each Sign (i.e., *Rāśi*) (i. e., 30^0, 60^0 and 90^0). Viz. 12, 21, 24. These are the degrees of declination (of the corrected Nonagesimal). These are South or North respectively (as the corrected Nonagesimal lies in the 6 Signs) from Libra or (the 6 Signs) from Aries.

(The Latitude of the Place)

3. अथ.... श्चाक्षभागाः. Subtract from 100 twice the *Aṅgula*s of the equinoctial shadow. Multiply this by the *Aṅgula*s of the equinoctial shadow and divide by 20. The result is the latitude of the place, always South.

(The Zenith distance of the Nonagesimal)

4. युक्ताः....स्युः. This declination and this latitude are to be added together or subtracted from each other according as their directions are the same or different. The result is the Zenith distance of the Nonagesimal in degrees.

(True Correction for Parallax in Longitude)

4. तदूनात्... 5. स्फुटतरमुदितम्. Subtract the above Zenith distance from 3 Signs (i.e., from 90^0) and find the sine declination of this (from what is given in verse 3). This is the 'multiplier' for Parallax in longitude. 24 is the 'divisor' for it. The sine for *Lamba* found before (verse 2) multiplied by the 'multiplier' and divided by the 'divisor' is the (partially) True parallax in longitude. For the set of difference in longitude between the Sun and the Nonagesimal given hereunder, there is a set of eight corresponding *Vināḍis*: 20, 38, 51, 56, 47, 28, 6 for intervals of half *Nāḍis*.

Take the *Vināḍis* for the difference, multiply it by the multiplier and divide by the divisor. The *Vināḍi*s become corrected. Add the corrected *Vināḍi*s to the (partially) True parallax in longitude and the result got is the True parallax.

(The Conjunction as corrected for Parallax)

5. तद्धनर्णे... मध्यम् . This is to be added to the conjunction or subtracted from it (according as the sine for *Lamba* is plus or minus as indicated in verse 2). This (is the Conjunction corrected for parallax and) is the middle of the Solar (eclipse).

(The Parallax in Latitude, the Latitude and the Corrected Latitude for the Solar Eclipse)

5. पुनरिह.... नतिः स्यात् . For the time of corrected conjunction, once again find the zenith distance of the Nonagesimal. Using this as the difference, find the sine for *Lamba*. Multiply this by the difference in degrees of the daily motion of the Sun and the Moon and divide by 60. This is the parallax in latitude.

6. अहिरहित...तुलाजात्. Find the Moon *minus Rāhu* for the time of the corrected conjunction. Find its *Bhujā* in minutes of arc. Multiply this by the daily motion of the Moon in degrees and divide by 149. These are the minutes of Latitude. These are to the south or north (as Moon *minus Rāhu* is in the 6 *Rāśis*) from Libra or from Aries.

6. नत्याः...क्षिप्तिरर्के. Add the Parallax in latitude with the Latitude if they have the same direction, and subtract one from the other if different. This is the Latitude (to be used) for the Solar (eclipse).

(The Beginning and Ending of the Solar Eclipse)

7. ऐक्यार्धात्... स्थित्यर्धम् . Find half the sum (of the angular diameters of the Sun and the Moon). Deduct the Corrected latitude from this. For the remainder equal to 2', 6', 12', 20' and 32' respectively there are the *Vināḍis* 55, 93, 125, 148 and 160 for the (rough) half-duration.

7. तद्युतोनं...सवितुः. Subtract and add the rough half duration to the original time of conjunction. Treating each as the time of conjunction find the conjunctions corrected for Parallax in longitude. They are the times of the beginning and ending of the Solar (eclipse).

(The Lunar Eclipse)

7. अथ विधोः... 8. मध्यं पर्व. Now for the Lunar eclipse. The corrected latitude is the Latitude (i. e., there is no parallax correction). The time of conjunction is the Middle of the eclipse.

8. अहिविध्वोः... स्थितिः स्यात्. Find half the sum of the angular diameters of the Shadow and the Moon. Deduct the latitude. For the remainder (equal to) 1', 5', 13', 28' and 56' respectively, are the *Nāḍikā*s 2, 4, 6, 8 and 9 for the whole duration. (Deducting or adding half the duration from and to the Middle of the eclipse gives its beginning and ending).

(Magnitude of the Eclipse)

8. वस्वष्ट्यंश... ग्रहांशः. In both (Solar and Lunar eclipses) half the sum (of the two angular diameters) minus the latitude is the part eclipsed. (The part eclipsed divided by the angular diameter of the body eclipsed is the Magnitude of the eclipse). If the Magnitude is less than 1/8 (in the case of the Sun) and 1/16 (in the case of the Moon) of the sum of the angular distances, the eclipses are not to be predicted.

(First and Last Contact)

8. पश्चात्...न्यथेन्दोः. In the Solar eclipse the first contact is on the west and the last contact on the east (of the Sun), and (in the northern or southern part) according as the Corrected latitude (is north or south). In the case of the Lunar eclipse it is just the opposite (i. e. the first and last contacts are on the east and west of the Moon, and in the northern part if the latitude is south, and in the southern part if the latitude is north.).

(Conclusion)

9. Thus has been composed the 'Octad on Eclipses' (*Grahaṇāṣṭaka*) by Parameśvara for the benefit of the dull witted. This mostly agrees with actual observation.

Thus ends the Octad on Eclipses.

Nīlakaṇṭha Somayāji (1444-1545 AD), The astute astronomer of Kerala and his works*

Nīlakaṇṭha Somayāji, the astute astronomer of Kerala and author of several works on Indian astronomy, shines as one of the brightest stars in the firmament of Indian astronomy. A versatile scholar, Nīlakaṇṭha initiated several new and accurate methods of astronomical computations relating to the instantaneous velocities of the planets, the eclipses, measurement of time from the Sun's and Moon's shadows and a host of other matters. To his credit go the depiction of a simpler and more accurate planetary model of the interior planets and the computation of the equation of centre. The novel theories envisaged in his works form a pointer to the great strides that the development of the astronomical and mathematical studies had taken in Kerala during medieval times.

Autobiographical details

Our author Nīlakaṇṭha is generally referred to with the title *Somayāji, Somasut, Somasutvan* or *Comatiri*, the last being the Malayalam derivative of the Sanskrit words. A detailed colophon occurring at the end of his *Bhāṣya* on the *Gaṇitapāda* of the *Āryabhaṭīya*, contains a good deal of information about him.[1]

इति श्रीकुण्डग्रामजेन गार्ग्यगोत्रेण आश्वलायनेन भाट्टेन केरलसद्ग्रामगृहस्थेन श्रीश्वेतारण्यनाथपरमेश्वरकरुणाधिकरणभूतविग्रहेण जातवेदपुत्रेण शंकराग्रजेन जातवेदो मातुलेन दृग्गणितनिर्मापकपरमेश्वरपुत्र-श्रीदामोदरात्तज्योतिषामयनेन रवित आत्तवेदान्तशास्त्रेण सुब्रह्मण्यसहृदयेन नीलकण्ठेन सोमसुता विरचितविविधग्रन्थेन दृष्टबहूपपत्तिना स्थापितपरमार्थेन कालेन शंकरार्य(भ)निर्मिते श्रीमदार्यभटाचार्यविरचितसिद्धान्तव्याख्याने महाभाष्ये....

The above-quoted passage informs that Nīlakaṇṭha belonged to the *Gārgya-gotra*,[2] was a follower of the *Āśvalāyana-sūtra* of the *Ṛgveda* and was a Bhaṭṭa. He was the son of Jātavedas and had a

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* *500 hundred years of Tantrasaṅgraha*, Ed. by M.S. Sriram, M.D. Srinivas and K. Ramasubramanian, Indian Inst. of Advanced Study, Shimla, 2002.

younger brother named Śaṅkara. He had an uncle Jātavedas by name and a close friend Subramaṇya. He was a performer of the *Soma* sacrifice. He had composed several works on astronomy, in which subject he had made deep and extensive investigations, a fact, which is well borne out by his available works.

Some more personal details about Nīlakaṇṭha seem to be forthcoming from a Malayalam work entitled *Laghurāmāyaṇam*. This work describes itself as a work of Rāma, son of Nīlakaṇṭha of the *Gārgyagotra* and resident of Kuṇḍagrāma. *Cf.*, colophon at its end[3];

इति श्रीकुण्डग्रामजेन गार्ग्यकुलतिलकेन श्रीनीलकण्ठात्मजेन आर्याम्बागर्भसम्भवेन मन्वादिस्मृतिमर्मज्ञ-संस्कृत-द्राविड-भाषा-त्रयपारीणस्य दक्षिणामूर्तिनाम्नोऽग्रजेन रामेण विरचितं श्रीरामायणं प्रबन्धम्।

This Nīlakaṇṭha is identified by the editor of the work with our author[4]. If this identification is correct, Nīlakaṇṭha's wife was named Āryā, and he had two sons Rāma and Dakṣiṇāmūrti, the latter of whom was well versed in the *Dharmaśāstras* and learned in the three languages, Sanskrit, Tamil and Malayalam. The great Malayalam poet Tuncattu Ezuttacchan is said to have been a student of Nīlakaṇṭha. Nīlakaṇṭha is also said to have composed, at the request of a friend, a panegyric in Malayalam on the goddess Pārvatī, the presiding deity of the temple of Ūrakam in Kochin, in order to ward off the predicted premature death of that friend's daughter[5].

The authenticity of the above work and the sources of the information are however not quite certain, and corroborative evidences have to be found before accepting the above statements.

Native Village and favourite deity

Nīlakaṇṭha hailed from Trik-kaṇṭi-yur (Sanskritised into Śrī-kuṇḍa-pura or Śrī-kuṇḍa-grāma), near Tirur, S.Rly. Ponnani Taluk, South Malabar, a famous seat of learning in Kerala during the middle ages. The name of his *Illam*, as the house of a Nampūtiri Brahmin is called, was Keḷallūr (sometimes spelt also as Kerallur and Kalannur), Sanskritised into *Kerala-sad-grāma* corresponding to the Malayalam word *Kerala-nall-ūr*[6]. Nīlakaṇṭha's house is identified as the present

Eṭamana Illam, situated a little to the south of the local temple[7]. It is stated that Nīlakaṇṭha's *family became extinct and that the family* property was inherited by the nearest relations, viz., the *Eṭamana* family.

Nīlakaṇṭha's favourite deity was Lord Śiva installed in the famous temple at Tṛpparaṅṅoḍ (Sanskrit, *Śrī-parakroḍa*, also *Śrī-śvetāraṇya* near his village, *cf*: श्वेतारण्यनाथ-परमेश्वर-करुणाधिकरणभूतविग्रहेण, in the colophon to the *Āryabhaṭīyabhāṣya*.

Patron, Netranārāyaṇa, and brother Śaṅkara

Nīlakaṇṭha refers to his younger brother Śaṅkara in several places in the *Āryabhaṭīyabhāṣya*. Śaṅkara too seems to have been well versed in astronomy and to have followed his elder brother's studies. Thus, after describing some method on the rule of three (*trairāśika*) in his *Āryabhaṭīyabhāṣya* (*Gaṇita*, 26), Nīlakaṇṭha says how his brother who was teaching at the house of his patron explained to the latter some of those theories[8]:

अत्र केषाञ्चिद् युक्तयः पुनः अस्मदनुजेन शंकराख्येन तत्समीपे अध्यापयता वर्तमानेन तस्मै (नेत्रनारायणाय) प्रतिपादिताः।

Nīlakaṇṭha observes at the close of the *Bhāṣya* on the *Golapāda* that he was entrusting the *Bhāṣya* to Śaṅkara for its proper propagation. Thus, just before the final colophon, Nīlakaṇṭha says[9]:

एवमिदम् अस्माभिर्यथामति व्याख्यातम्। नमः स्वयम्भुवे तस्मै यत्प्रसादादिदं कृतम्। नमो भगवते तस्मै श्रीमदार्यभटाय च। शिष्यं तत्त्वेन विचार्यार्यभटसूत्रभाष्यमिदम्। यदि स न्यायाल्लिप्सेदस्मै दातव्यमेव शंकर ते।।

That Nīlakaṇṭha was intimately connected with and was patronised by Kauṣītakī Āḍhya Netranārāyaṇa, known locally as Azhvāñceri Tamparakkal, the religious head of the Nampūtiri Brahmins of Kerala, is known from several references in his writings. It is also clear that the patron had great esteem for Nīlakaṇṭha's erudition in astronomy, in which subject he too was interested and used to discuss difficult points with Nīlakaṇṭha. Thus, in the discussion on the calculation of the motion of planets (*Āryabhaṭīya*., *Kāla*., 22-25), Nīlakaṇṭha says[10]:

कर्णभुक्तिः स्फुटेत्यत्र व्याख्याने पारमेश्वरे।
व्यासार्धाप्तं कोटिवर्गात् कर्क्येणादावृजं धनम्।।
कोट्यां तदूनयुग्म्यासदलं गतिविधौ श्रुतिः।
प्रकारान्तरमाहैवं सूक्ष्मभुक्तिप्रसिद्धये।।
गुरूणां मे पितात्रापि स्थौल्यान्मत्सरिणोदिते।
परमेश्वरतच्छिष्या नैव वेलागतिं विदुः।।
इति कौषीतकी श्रुत्वा नेत्रनारायणः प्रभुः।
मह्यं न्यवेदयत् तस्मै तदेवं प्रत्यपादयम्।।

Again, in the long discussion on the calculation of the apparent position of celestial bodies (*Āryabhaṭīya.*, *Kāla*, 17-21), speaking on a method to derive the *sakṛt-karṇa*, our author says[11]:

अन्यदपि कर्म अस्माभिरुपन्यस्यमानं श्रुत्वा आढ्येन कौषीतकिना अनुष्टुभा निबद्धम् -
स्वोच्चोनमध्यमार्कस्य भुताज्याघ्ना त्रिजीविका।
स्वोच्चहीनस्फुटार्कस्य दोर्ज्याभक्ता श्रुतिर्भवेत्।।

This would indicate the intimacy that existed between Nīlakaṇṭha and his patron and the common interest that bound them together. On the compilation of the *Āryabhaṭīyabhāṣhya*, Nīlakaṇṭha observes in one place[12]:

यन्मयात्र केषाञ्चित् सूत्राणां तदुक्तीः प्रतिपाद्य कौषीतकिना आढ्येन नारायणाख्येन व्याख्यानं कारितम्, अतस्तदेवात्र लिख्यते।

Again, in another context, he remarks[13]:

इतीदं प्रथमे वयस्येव, वर्तमानेन मया द्वितीयवयसि स्थितेन कौषीतकिना आढ्येन कारितम्।..।.. तस्मिन् स्वर्गते पुनः.....व्याख्यानमारब्धम्।

It is clear from the above that the credit of enthusing Nīlakaṇṭha in his investigations, and in fact, to have prompted him to write his *Āryabhaṭīyabhāṣhya*, goes to Netranārāyaṇa,[14] the members of whose family are known all through the annals of Kerala history to have been good scholars and, at the same time, liberal patrons of scholarship.

Nīlakaṇṭha's teachers : Ravi and Dāmodara

Nīlakaṇṭha informs us in his *Āryabhaṭīyabhāṣya* that he studied *Vedānta* under Ravi, *cf. Ravita ata-vedānta-śāstreṇa*[15]. That Ravi was

well versed also in *Jyotiśśāstra* and that Nīlakaṇṭha imbibed some of his knowledge in astronomy also from Ravi is clear from the introductory verse to Nīlakaṇṭha's *Siddhāntadarpaṇa*, where his teachers have been mentioned by double entendre:

श्रीमद्दामोदरं नत्वा भगवन्तं रविं तथा।
यत्प्रसादान्मया लब्धं ज्योतिश्चरितमुच्यते।।

A work on astrology, *Ācāradīpikā*, which is a detailed commentary in verse on *Muhūrtāṣṭaka*, is ascribed to this Ravi[16].

The teacher of Nīlakaṇṭha who actually initiated him into the science of astronomy and instructed him on the various principles underlying mathematical calculations was Dāmodara, son of the *Kerala-Dṛgganita* author Parameśvara[17], of the *Bhārgava-gotra* and resident of the village of Alattur (Sanskritised into Aśvattha-grāma) which was situated quite near Nīlakaṇṭha's own village. In his *Āryabhaṭīyabhāṣya*, as also in his other works, Nīlakaṇṭha reverentially refers to his teacher and his studies under him. He speaks of how even as a boy he stayed with his *Guru*, at the latter's residence, prosecuting his studies[18]:

मया गुरुकुले वसता बाल्य एव . . . . . . निबद्धं च तत् तदेव अस्मद्गुरुभिः पञ्चभिरुपजातिभिः अर्कस्फुटेनानयनं प्रकुर्याद्. . . । तदपि सर्वत्र विष्कम्भदलं श्रुतौ वा व्यासार्धके स्याद् विपरीतकर्णःइत्यस्मद्गुरुणोक्तम्।[19]

Similar quotations and other references, which Nīlakaṇṭha and later authors make, proclaim Dāmodara not only to be a prominent astronomer of the times but also as the author of erudite works on the subject, manuscripts of which are yet to come to light.

Nīlakaṇṭha followed the footsteps of Parameśvara, founder of the *Dṛgganita* system of astronomy in Kerala and one of the foremost astronomers of the land. For him Parameśvara was not only the revered father of his *Guru* but was also his *Paramaguru*, by which term he generally refers to him in his works:

यतो भार्गवपरमेश्वराचार्येण अस्मत्परमगुरुणा चलांशास्स्वं (4546) इति कल्यब्दे परीक्ष्य पञ्चदशांशपूर्तिर्निर्णिता।[20]; अस्मत्परमगुरुणापि सिद्धान्तदीपिकायाम् एतत् प्रतिपादितम्।[21]

Date of Nīlakaṇṭha

Indisputable evidences are available for fixing the date of our author. Śaṅkara, Nīlakaṇṭha's pupil, in his commentary on his teacher's *Tantrasaṅgraha* points out that the first and last verses of that work contain chronograms specifying the dates of the commencement and of the completion of the work. Thus, after giving the literal meaning of the first verse of the work[22]:

हे विष्णो निहितं कृत्स्नं जगत् त्वय्येव कारणे।
ज्योतिषां ज्योतिषे तस्मै नमो नारायणाय ते ।।

Śaṅkara says:

आचार्येण इमं श्लोकं आदितो ब्रुवता प्रथमपादेन प्रबन्धारम्भदिनकल्यहर्गणश्च अक्षरसंख्यया उपदिष्टः। समाप्तिसमयाहर्गणश्च 'लक्ष्मीशनिहितध्यान' इत्यन्ते भविष्यति।

These two *Kali* dates, 16,80,548 and 16,80,553, work out to *Kali* year 4601, *Mīna* 26, and 4602, *Meṣa* 1, both dates[23] occuring in A.D. 1500.

The *Siddhāntadarpaṇa* and Nīlakaṇṭha's own commentary thereon give, respectively, the year and actual date of his birth[24],

कलिसन्ध्यष्टमांशे स्वशतांशाढ्ये गते ततः।
धनुर्मिथुनयोर्मध्ये प्रायशस्त्वयने उभे।।

दिव्याब्दशतमिता खलु काले सन्ध्या स्मर्यते। तस्य अष्टमांशः सार्धदिव्याब्दद्वादशकः। स च सौराब्दानां पञ्चचत्वारिंशत् शतम् (४५००)। तस्य शतांशः पञ्चचत्वारिंशदब्दः (४५)। ततः स्वशतांशाढ्यः 'शिवशिवे'ति (४५४५)। कल्यब्दैस्तावति याते उभे अयने उत्तरदक्षिणाख्ये प्रायशो धनुर्मिथुनमध्ये स्तः। तदा अयनचलनांशाः धनात्मकाः पञ्चदशसंख्या बभूवुः। प्रायिकत्वं च कलाष्टकाधिकत्वात्। यतो भार्गवपरमेश्वराचार्येण अस्मत्परमगुरुणा 'चलांशास्त्वं' (४५३६) इति कल्यब्दे परीक्ष्य पञ्चदशांशपूर्तिर्निर्णीता। अतः सन्ध्याष्टमांशशतांशस्य प्रायिकत्वम्। स्वजन्मकालज्ञापनार्थं चैवमुक्तम्। तदा अहर्गणश्च 'त्यजाम्यज्ञतां तर्कैः।' (१६,६०,१८१) इति।

(p. 17 of the edn).

Here, Nīlakaṇṭha himself says that he was born on the *Kali* day 16,60,1881, which corresponds to June 17, 1444 A.D. according to Gregorian calendar.

That Nīlakaṇṭha lived to a ripe old age, even to become a centenarian, is attested by a contemporary reference made to him in a Malayalam work on astrology, viz., the *Praśnasāra* by Mādhava, a *Nampūtiri Brāhmaṇa* of the Iñcakkāḷavā house in Kerala, who wrote his work in A.D. 1542-43. Here, Mādhava says that he could count upon reputed authorities like Keḷanallūr to recommend his work.

āḷ-āyat-ādaravil ādiyil attimaṭṭam
lōkōttaran punar itinn-iha 'keḷanallūr' ।
ābhāsar allarivatuḷḷavar ādarippān
porum prasiddhi perikoḷḷavar uṇṭanekam ॥

The date of composition of this work, *Praśnasāra*, is given as Kollam era 718/*Kali* 4644 (A.D. 1543) by the following verse in the work itself:

eḷunūṭṭorupatteṭṭavatu kollam atāya nāḷ ।
varunna viṣuvad, bhāvatattvam (4644) kalyabdam āyatu ॥

Rightly does Nīlakaṇṭha remark in his *Āryabhaṭīyabhāṣya* [25]:

मयाद्य प्रवयसा. . . . . . यथाकथञ्चिदेव व्याख्यानमारब्धम् ।

Moreover, we know of at least two more works composed by him subsequent to his writing the *Āryabhaṭīyabhāṣya*, viz., the commentary on the *Siddhāntadarpaṇa* and the *Jyotirmīmāṃsā*, both of which quote the *Āryabhaṭīyabhāṣya*.

Versatility of Nīlakaṇṭha :

For a *Jyautiṣika*, and one who had specialized on its astronomical aspect, Nīlakaṇṭha seems to be very well read. Every other page of his writings substantiates his knowledge of the several branches of Indian philosophy and culture; Sundararāja, the Tamil astronomer calls him '*Ṣaḍdarśanapāraṅgata*' 'One who had mastered the six systems of philosophy'. Nīlakaṇṭha himself informs us that he studied *Vedānta* under *Ravi*: *cf.*, *Ravita ātta-vedānta-śāstreṇa*. He can refer to a *Mīmāṃsā* authority to establish a mathematical point[26] and with equal felicity apply a grammatical dictum to the same purpose.[27] Piṅgala's *Chandas-sūtra*[28] and the lexicons are quoted as

the occasion demanded. The scriptures and the *Dharmaśāstras* also come in for citation,[29] and, so also the *Purāṇas*[30] like the *Bhāgavata*[31] and the Viṣṇu.[32]

As for *Jyotiṣa* works, Nīlakaṇṭha exhibits a surprising familiarity with a large number of them, from the *Vedāṅgajyotiṣa* down to the treatises of his own times. He uses all types of *Jyotiṣa* texts, *Gaṇita*, *Saṃhitā* and *Horā*, but as became his subject of specailisation, his quotations are mainly from texts dealing with astronomy proper. Some of the more important texts of all India prevalence that Nīlakaṇṭha quotes are: *Vedāṅgajyotiṣa*, *Āryabhaṭīya*, Varāhamihira's *Pañcasiddhāntikā*, *Bṛhajjātaka* and *Bṛhatsaṃhitā*, *Sūryasiddhānta*, Śrīpati's *Siddhāntaśekhara* and Mañjula's *Laghumānasa*. Of the texts popular mainly in Kerala may be mentioned, the *Parahitagaṇita* or *Grahacāranibandhana* of Haridatta, the *Bhāṣya* on the *Āryabhaṭīya* and *Laghu* and *Mahā-bhāskarīyas* by Bhāskara I, Govindasvāmi's *Bhāṣya* on the latter and Parameśvara's super-commentary thereon. Other works of Parameśvara like his *Āryabhaṭīya-vyākhyā* also come in for citation as also passages from his own teacher Dāmodara. Another Kerala author whom Nīlakaṇṭha quotes often is Mādhava, often styled *Golavid*, who was a reputed astronomer of the times.[33] Manuscritps of several works quoted by Nīlakaṇṭha are yet to be unearthed and a detailed study of the numerous authorities quoted by Nīlakaṇṭha is bound to throw welcome light on the annals of Hindu astronomy.

Nīlakaṇṭha's works

Nīlakaṇṭha has written several works which reflect his deep study of and ripe scholarship in astronomy, embodying the results of his investigations in the subject and interpreting the science lucidly.

i. *Golasāra*[34]

The *Golasāra* is a short work in 56 *āryā* verses, divided into three *parichhedas*, containing, respectively, 11, 15 and 30 verses. The first *pariccheda* sets out the basic astronomical constants, viz., the number of civil days and the revolutions of the planets in an aeon, the positions of the higher apses and the ascending nodes of the planets,

their maximum latitudes, their epicycles to the equations of the apses and of conjunction, the diameters of the orbits of the Sun and the Moon and the *yojana* measures of the epicycles.

Pariccheda II is concerned with the presentation of the celestial globe (*Jyotirgola*) from the point of view of astronomical conceptions and observations and the movement, therein, of the heavenly bodies. The position of the great circles, *Ghaṭikā-maṇḍala* (celestial equator) and the *Apakrama-maṇḍala* (ecliptic), their mutual obliquity, the division of the ecliptic, the (apparent) rotation of the celestial globe, the rising point of the ecliptic (*lagna*), the measure of the orbits of the planets, the measurement of the positions of the planets on the ecliptic and the position of the horizon at the equator and elsewhere are noticed here, in order.

In *Pariccheda* III, verses 1 to 15 deal with the circle and the graphical and computational derivation of the sines. Verses 16 to 30 discuss the inter-relationship of the *Manda*, *Śīghra* and *Kakṣya* circles of the different planets and also how the results arrived at by calculation of the positions of the planets are affected by their *Kṣepa* (deflection) from the ecliptic.

ii-iii. *Siddhāntadarpaṇa* and *Vyākhyā* [35]

The importance of *Siddhāntadarpaṇa* lies in the fact that the author presents herein the astronomical constants as verified through his own observations and investigations. The passages expressing these constants having been adopted and commented upon by the author in his commentary, which latter happens to be one of his last works. It could be taken that the values of the constants as given herein are the final figures accepted by Nīlakaṇṭha.

In the first part of the work called *Upadeśa-bhāga* (theory section), the author enunciates in twenty couplets (2-21), his view on the number of revolutions of the planets, their higher apses (*mandocchas*) and ascending nodes (*pātas*) during a definite period of time, the dimensions of the epicycles of equations of the apses (*manda-paridhi*) and of conjunctions (*śīghra-paridhi*), the measure of the aeons

(*yugas*), the velocities of the planets, the measures of the diameters of the Moon and the Sun, the geographical location of the city of Avantī, the situation of the ecliptic (*apakrama-vṛtta*) and the conception of the epicycles.

In the second part called *Nyāyabhāga* (Practical section) verses 21-31), are set forth the eccentric and orbital circles (*pratimaṇḍala* and *kakṣyā-maṇḍala*), the sines etc. of the angles measured on these circles, the geocentric positions of the planets, declination and its measurement. The author also gives his views on the occurrence of the *vyatīpāta*s, the extent of the lunar crescent and the data from which eclipses are to be calculated.

The commentary

In line with his *Bhāṣya* on the *Āryabhaṭīya*, Nīlakaṇṭha's commentary on the *Siddhāntadarpaṇa* is elaborate and discursive. Alongside explaining the text proper, it introduces related topics by way of background, illustration and rationalization. Often, the commentary dilates into verse, a common practice with Kerala astronomers like Parameśvara. This feature is found also in Nīlakaṇṭha's *Āryabhaṭīyabhāṣya*.

Nīlakaṇṭha's discussions are often highly instructive. An instance in point is his detailed analysis of the mental working of a mathematician who proceeds to derive the relation between the sides and the hypotenuse of a right angled triangle (pp.22-24). In the course of this discussion, he makes a mention also of the two methods of approach for solving mathematical problems, viz., that of logical reasoning and that of demonstration on the board. He adds that one should try the method of demonstration, for logical reasoning is limited, endless and sometimes inconclusive (*alpa-viṣayatvāt, ānantyāt, kvacid apy aviśrānteś ca*, p.23). Equally instructive are the methods of constructing the armillary sphere, the defining of the situation of *rāśis* therein (p.14), and the exposition of the computation of the geocentric positions of the planets (pp. 25-31).

The following observations of Nīlakaṇṭha are noteworthy:

(i) *Ayanāṃśa* (measure in minutes of the precession of the equinoxes) should be derived by observation, if it has to be accurate (p.17).

(ii) The use of *Trairāśika* (Rule of three) is justified even in computations concerning moving bodies, since the factors involved are considered, only for specific moments at which they might be taken as stationary (p.25)

(iii) In astronomical computations, it does not make any difference whether the eastward motion of the Earth or the westward motion of the planets are taken, because the motion is relative (p.5).

(iv) The *Bhagola* (*Rāśigola*, ecliptic sphere) revolves as a whole and not *Vāyugola* (having the *Ghaṭikāmaṇḍala* or Celestial equator as one of its great circles); thus the relative distances between the stars remain constant, from which other results follow (pp.16-17).

iv. v. *Candracchāyāgaṇita* and *Vyākhyā* [36]

Chāyāgaṇita or 'Computations concerning the Shadow' constitutes the Hindu astronomer's method for ascertaining the exact time of occurrence of any event on the basis of the shadow cast by the Sun or the Moon. The expediency of this device during ancient and medieval times would be apparent when one considers the limitations of such chronometrical devices as the hour-glass, water disc, etc. The gnomon, being one of the simplest of astronomical instruments that could be set up at any time and at any place, and readings made independent of circumscribing factors like zero-point etc., is the most handy instrument to record such abrupt occurrences as the birth of a child, death of a person, etc. A knowledge of the exact moment of these happenings, as computed by astronomical methods from the measure of the shadow, facilitates the prediction of the future based

on them in accordance with the dictums of astrology. Obviously the shadow cast by the Sun is measured during day and that by the Moon during night.

The *Candracchāyāgaṇita* of Nīlakaṇṭha Somayāji, belongs to this genre of texts and sets out the processes for the computation both of *Kramacchāyā*, 'Shadow from Time' (verses 1-17), and *Viparītacchāyā*, 'Time from shadow' (verses 18-32), of the Moon. The commentary by Nīlakaṇṭha himself gives a lucid exposition of the textual verses.

Kramacchāyā and *Viparītacchāyā*

The utility of *Chāyāgaṇita* in the daily life of the medieval Hindu, whose prescribed way of life required the performance of numerous religious rites, is not far to seek. Ordinary astronomical computations enabled him to calculate auspicious times (*muhūrta*) for sacred rites and social functions, in terms of time-units like *nāḍikā*s and *vināḍikā*s, say, after Sunrise or Sunset. But, in the absence of accurate chronometers, it was not easy to ascertain when that auspicious moment, as calculated, had arrived. *Chāyāgaṇita* came to his rescue in such a situation. For, it was possible to calculate, in advance, the length that the Sun's or the Moon's shadow would attain at the appointed time. One could, then, set up the gnomon and watch for the shadow to reach the stipulated length and perform the rite at the right moment. This process of computing the shadow for any specific time is called *Kramacchāyā*, 'Direct (process of) Shadow (computation)'.

The converse of *Kramacchāyā*, is known as *Viparītacchāyā*, 'Reverse (process of) Shadow (computation)', according to which time is calculated from the length of the shadow. This was equally, if not more, important in everyday life, in that it enabled the accurate ascertainment of the time of abrupt, non-planned occurrences like moments of birth and death, unexpected arrivals, untoward happenings and the like.

Popularity of *Chāyāgaṇita* in Kerala

The medieval astronomers of Kerala seem to have taken the best advantage of this natural phenomenon and devised highly intricate calculations to get the exact times corresponding to the measures of the shadow, taking into consideration also the factors that affected the shadow, such as the latitude and longitude of the place, time of the year, precession of the equinoxes, etc. Practically every one of the numerous astronomical manuals (*Karaṇa granthas*) produced in Kerala contains sections devoted to *Chāyāgaṇita*, both of the Sun and of the Moon. In the *Pañcabodha* manuals, of which about a dozen different texts have been identified and documented, *Chāyā* is one of the five subjects dealt with, the others being *Vyatipāta, Grahaṇa*, *Śṛṅgonnati* and *Mauḍhya.* Several texts which are devoted solely to computations based on shadow have also been composed.

vi. *Tantrasaṅgraha*

Tantrasaṅgraha composed on the model of the '*Tantra*' class of astronomical texts in which the zero point for computation is taken as the commencemet of the *Kaliyuga* as in texts like the *Āryabhaṭīya*, is a major work of Nīlakaṇṭha. Perhaps, to be in tune with tradition, Nīlakaṇṭha makes use of the *bhūtasaṅkhyā* notation of all India prevalence in place of the Kerala system of *kaṭapayādi*, which he uses in his other works. In about 432 verses, mostly couched in the *anuṣṭubh* metre, the author depicts the entire gamut of theoretical and practical astronomy in eight sections entitled *prakaraṇas*: I. *Madhyama* (Mean planets), II. *Sphuṭa* (True planters). III *chāyā* (Gnomonic shadow), IV. *Chandragrahaṇa* (Lunar eclipse), V. *Ravigrahaṇa* (Solar eclipse), VI. *Vyatīpāta* (The 'aspect' of the Sun and the Moon when the sum of their longitudes is 180 and their declinations (*krānti*) are equal in magnitude and direction), VII. *Dṛkkaraṇa* (Reduction to observation), and VIII. *Śṛṅgonnati* (Elevation of the Moon's horns).

The initial verse of the work gives, in a chronogram, the date of the commencement of the work and the last verse, in another chronogram, the date of completion of the work, both in 1500 A.D.

with five days intervening between them; while this may seem to be too short for the composition of the work, it need not be so; for a literary giant and idea-filled astronomer this is not a difficult feat.

Through *Tantrasaṅgraha*, Nīlakaṇṭha explores new fields, formulates novel ideas and introduces major revisions as in the case of the inner planets Mercury and Venus in the matter of their planetary model and the better formulation of their equation of centre.

The two commentaries, *Yuktidīpikā* and *Laghuvivṛti* both by Śaṅkara, on the *Tantrasaṅgraha* are highly useful in understanding the text, especially the former. It is, indeed, a real *Yuktidīpikā* in that it offers lucid rationales to the statements in the text.

Manuscritps of *Tantrasaṅgraha*

The *Tantrasaṅgraha* is divided into eight chapters, and contains 432 verses in all. Since the work had been popular and was accepted as an authority, a large number of manuscripts of the work exist, of which about fifty have been documented in the *New Catalogus Catalogorum,* (Madras University, Vol. VIII, 1974, p.97). One of these manuscripts, No.475-E of the Kerala University Oriental Research Institute and Manuscript Library, gives the date of its transcription through the chronogram '*sevyo dugdhābdhitalpaḥ*', being *Kali* day 16,99,847, falling in the year A.D. 1551, and so this Ms. is almost contemporaneous with its author Nīlakaṇṭha Somayāji who passed away in about AD 1545. All the said documented manuscripts conform to the division and extent of the work as mentioned above. In several cases there are post-colophonic statements expressing the completeness of the work in eight chapters. In one such manuscript, dated M.E. 928 (AD 1753), being Ms. No. C.224-C, deposited in the said Library, the total number of verses in the work is also stated to be 432, which conforms to the presently available text.

इति तन्त्रसंग्रहे अष्टमोऽध्यायः। तन्त्रसंग्रहः समाप्तः। अध्यायं एट्टिलुं कूटि श्लोकङ्ङळ् नानूट्टिमुप्पत्तिरण्टु। ९२८- माण्ट् चिङ्ङमासत्तिल् एषुतिञ्ञ पुस्तकम्।।

vii. *Āryabhaṭīyabhāṣya*[38]

Āryabhaṭīyabhāṣya is an elaborate commentary on the cryptic and *sūtra* like text of *Āryabhaṭīya* which comprehends in 121 *ārya*s the fields of Mathematics and Astronomy. A perusal of the commentary will amply prove that it is no false claim that Nīlakaṇṭha makes when he designates his work as a '*Mahābhāṣya*' and explains the method of exposition adopted by him [39].

श्रीमदार्यभटाचार्यविरचितसिद्धान्तव्याख्याने 'महाभाष्ये' उत्तरभागे युक्तिप्रतिपादनपरे त्यक्तान्यथाप्रतिपत्तौ निरस्तदुर्वाख्याप्रपञ्चे समुद्घाटितगूढार्थे सकलजनपदजातमनुजहिते निदर्शितगीतिपादार्थे सर्वज्योतिषामयनरहस्यार्थनिदर्शके समुदाहृतमाधवादिगणितज्ञाचार्यकृत-युक्तिसमुदाये निरस्ताखिलविप्रतिपत्तिप्रपञ्च-समुपजनितसर्वज्योतिषामयनविदमलहृदय-सरसिजविकासे निर्मले गम्भीरे अन्यूनातिरिक्ते गणितपादगतार्यात्रयस्त्रिंशद्व्याख्यानं समाप्तम्।

In another context, recalling how he came to write the commentary, Nīlakaṇṭha remarks [40]:

मयाद्य प्रवयसा ज्ञाता युक्तीः प्रतिपादयितुं भास्करादिभिरन्यथाव्याख्यातानां कर्माण्यपि प्रतिपादयितुं यथाकथञ्चिदेव व्याख्यानमारब्धम्।

The lucid manner in which the difficult conceptions about the celestial globe and astronomical calculations are made clear, the wealth of quotations, and the results of personal investigations and comparative studies presented herein amply justify the appellation *Mahābhāskarīya* which Nīlakaṇṭha has given to his work.

Nīlakaṇṭha has commented only on the *Gaṇita*, *Kālakriyā* and *Golapāda*s of the *Āryabhaṭīya*, leaving out the *Gītikāpāda*, which he says is covered by the commentary on the other three sections[41]:

तत्रेयं त्रिपाद्यस्माभिर्व्याचिख्यासिता, यतस्तद् व्याख्येयरूपत्वाद् गीतिकापादस्य। एतद् व्याख्यानेनैवार्थः प्रकाशेत।

viii. *Grahaṇanirṇaya*

This is a work on the computation of lunar and solar eclipses. Manuscripts of this work are yet to be discovered, but later authors and Nīlakaṇṭha himself in his *Āryabhaṭīyabhāṣya* quote from this work[42]:

तदैव ग्रहणमध्यं च। स्फुटसाम्ये तु विक्षेपकोटिमण्डलापक्रममण्डलयोः भुक्तभागसाम्यमेव स्यात्। तदुक्तं मया ग्रहणनिर्णये-

परमक्षेपकोटिघ्नः पातोनार्कभुजागुणः।
स्वेष्टविक्षेपकोट्याप्तस्तत्क्षेपकृतियोगतः।।
पदं यच्चापितं यच्च पातोनार्कभुजाधनुः।
तद्विशेषं हतं षष्ट्या गत्यन्तरहृतं क्षिपेत्।।
पर्वान्ते युक्पदे क्षेपे शोधयेद् विषमे पदे।
एवं कृतोऽपि पर्वान्तः सूर्येन्द्वोर्ग्रहणे स्फुटम्।।

These verses are quoted also by Śaṅkara in his commentary *Laguvivṛti* on Nīlakaṇṭha's *Tantrasaṅgraha*[43] with the introductory remark: तदुक्तमनेनैव ग्रहणनिर्णये।

ix. *Sundararāja-praśnottara*

Sundararāja, son of Anantanārāyaṇa, was an astronomer of the Tamil country contemporaneous with Nīlakaṇṭha and author of a detailed commentary on the *Vākyakaraṇa* or *Vākyapañcādhyāyī* which is a manual on the basis of which almanacs are computed in the Tamil districts.[44] Sundararāja had the greatest respect for Nīlakaṇṭha whom he addressed for clarification of certain points in astronomy. Nīlakaṇṭha's detailed answers to these questions formed a regular work, *Sundararājapraśnottara*. Manuscripts of this work are yet to come to light, but both the authors refer to this work. Sundararāja in his commentary on the last verse of Ch.V of the *Vākyakaraṇa* says:[45]

अत्र तु गतियोगांशकेनैव हरणं युक्तमिति श्रीमत्-केरलसद्ग्रामनिवासि-नीलकण्ठार्येण त्रिस्कन्धविद्यापारदृश्वना षड्दर्शनीपारंगतेन आश्वलायनसूत्रेण गार्ग्यगोत्रेण नवकलरु(?)जातेन गोलचूडामणिना अस्मदनुग्रहार्थे सुन्दरराजप्रश्नोत्तराख्ये ग्रन्थे प्रतिपादितम्। तेन गतियोगेनैव विभज्य स्थितिदलं ज्ञेयम्।

Nīlakaṇṭha too refers to this work in his *Āryabhaṭīyabhāṣya*[46], सुन्दरराजप्रश्नोत्तराख्ये मयोक्तमत्राप्यनुसन्धेयम्।

x. *Grahaparīkṣākrama*

The well-known Kerala astrologer, the late Puliyūr Puruṣottaman Nampūtiri, has edited[47] an old incomplete Malayalam summary of a

Sanskrit work under the title *Grahaparīkṣākrama*. The textual verses were not available to the editor and he presumed that the author was Dṛggaṇita-Parameśvara. These verses are, actually, to be found in Nīlakaṇṭha's *Bhāṣya* on the *Golapāda* of the *Āryabhaṭīya*[48]. It is a long tract with about 200 verses, enunciating the principles and methods for verifying astronomical computation by regular observation. The work, as available, ends thus:

इति संक्षेपतः प्रोक्ता परीक्षा ज्योतिषामिह ।
कालमानचतुष्कस्य श्रुतस्य विवृतिस्त्वियम् ।।

xi. *Jyotirmīmāṃsā* [49]

The *Jyotirmīmāṃsā* of Nīlakaṇṭha is a unique work, the like of which does not seem to exist in Indian astronomical literature. It asserts that astronomy is primarily a discipline of observation, experimentation and computation and deserves to be revised periodically if the results are to be true. The processes to be employed and comparative studies to be made in different cases have also been duly indicated. For this reason, the work deserves to be set out in greater detail than the other writings of Nīlakaṇṭha.

a. Real implication of 'divine instruction'

At the outset, Nīlakaṇṭha draws attention to two eclipses which actually occurred during his times, but whose presence would not have been detected had they been computed through the astronomical constants given in the *Gītikāpāda* of the *Āryabhaṭīya*. Nīlakaṇṭha explains that it was for this very reason that Āryabhaṭa intended astronomy to be a practical discipline and recommended the verification and revision of his own astronomical constants by observation, towards which he had also suggested the method in *Golapāda* 48 (pp. 1-2). To a possible query that the number of planetary revolutions given by Āryabhaṭa are immutable since they form part of divine instruction, Nīlakaṇṭha points out, pertinently, that by the expression 'divine instruction' is not meant any direct instruction by the gods, but only the chastening of the intellect through divine grace, as a result of which the author could express his thoughts logically (pp. 2-3).

b. *Jyotiṣa*, an observational science

Nīlakaṇṭha then takes pains to demonstrate the place of observation and logical inference in the maintenance and furtherance of astronomical tradition (pp. 6-10). A passage from a *Mīmāṃsā* text, which Nīlakaṇṭha quotes in this context, fully expresses his idea:

The correlation, of the computed Moon etc. with actual observation at a particular place, the revision of computation on the basis of such correlation, logical inference there from being transmitted as tradition, it being again correlated (with observation and again revised) and transmitted further down to others - this is how tradition is continued without interruption, and hence its (continued) authoritativeness[50]. In the same vein Nīlakaṇṭha argues:

One has to accept that each of the five *Siddhāntas* had been authoritative at one time (or other, though they might not be so, now). Therefore, one has to look for a system which tallies with observation. The said tallying has to be verified by contemporary experimenters at the time of eclipses. When the two vary, i.e., when an earlier system does not agree (with observation), experiments have to be conducted with instruments, and revolution numbers of the planets calculated there from. A new system has thus to be expounded. Nobody will be ridiculed for this in this world nor punished in the next[51].

c. Corrections to planetary parameters

Having established the necessity of revising planetary parameters, periodically, Nīlakaṇṭha presents the corrections propounded to the parameters of *Āryabhaṭīya* at different times by certain astronomers including Haridatta, Govinda, Brahmagupta and Lalla (pp. 10-12).

A point of interest centres round two sets of corrections, one by Haridatta, commencing from *Śaka* 444 (*Kali* 3623) as given in his *Grahacāranibandhana*, and the other by Lalla, commencing from *Śaka* 420 (*Kali* 3599) as given his *Śiṣyadhīvṛddhida*. Both these corrections are presumed to have commenced from the date of composition of

the *Āryabhaṭīya* given in verse 10 of the *Kālakriyāpāda*. Nīlakaṇṭha points out that the discrepancy between the dates as accepted by the two authors has arisen on account of the different interpretations, the former taking *Kali* 3600 mentioned in the verse as the date of birth of Āryabhaṭa and the latter as the date of composition of the *Āryabhaṭīya*. While discussing the correction advocated by Haridatta, Nīlakaṇṭha notes that his interpretation was wrong and that *Kali* 3600 was actually the date of composition of *Āryabhaṭīya* (pp. 13-14).

Nīlakaṇṭha takes the occasion to draw attention also to the apparent error in Lalla's commencing the correction from *Śaka* 420 (*Kali* 3599) instead of from *Śaka* 421 (*Kali* 3600), but justifies it on two grounds: (1) 420 which is a round figure is more amenable to mathematical operations and increases the resultant but by one, whatever be the year for which readings are taken, causing thereby but negligible difference in the result. (2) In the case of the Moon such an addition is actually warranted. Especially for the second reason, Nīlakaṇṭha goes to the extent of saying that Lalla had used the figure 420 intentionally for this purpose (pp.14-17).

A similar justification has been made also by Sūryadeva-yajvan (born AD 1191) in his commentary on the *Āryabhaṭīya*. Nīlakaṇṭha extracts the entire section from Sūryadeva in order to buttress his view (pp.19-20).

d. Reason for different Means for same revolutions

The author poses a question as to how the means of certain planets calculated according to different systems differ even though the numbers of their revolutions per *Kalpa* as given in the said systems are the same. In answer, it is demonstrated that it is so because the number of civil days in *Kalpa* differs in the different systems, resulting in a corresponding difference in the means also (pp.17-19).

e. Vedic authority for inference in astronomy

Earlier in the work (pp. 3-6), Nīlakaṇṭha had stressed the significance of logical inference in the matter of astronomical computation. Vedic approbation in the matter is sought to be provided

by a reference to a passage from the *Taittirīya-āraṇyaka*, 1.2.1, as expounded by the well-known Vedic scholiast Sāyaṇa- Mādhava in his work *Kālanirṇaya*. It is specified in the said passage that *Smṛti, Pratyakṣa, Aitihya* and *Anumāna* (Inference) are means to determine the periods of planetary motion (pp. 21-22).

f. Relative accuracy of different systems

For an estimation of the relative accuracy of the different systems, Nīlakaṇṭha adopts the ingenious method of computing the planets for a common date. For this purpose *Kali* day 16,82,112 is chosen, it being a date occurring in A.D. 1504 and, so, contemporary to his own times. This date has the advantage also of being 8/75,00,000 of a *Kalpa*, which makes calculations easy. The results obtained are then correlated to observation.

In this connection, Nīlakaṇṭha takes into consideration the Sunrise and Midnight systems (*Audayika* and *Ārdharātrika pakṣas*), both of Āryabhaṭa, and those of Brahmagupta and Śrīpati, as set out in *Brahmasphuṭasiddhānta* and *Siddhāntaśekhara*, composed respectively by the latter two authors (pp. 22-31).

g. Correction through eclipses

Well defined eclipses being the most convenient natural phenomena for the verification of astronomical systems and effecting corrections thereto, the utilization thereof is stressed by Nīlakaṇṭha. He instructs as follows, in this connection:

The eclipses illustrated in the *Siddhāntadīpikā* might be computed (in all their details) by the investigator. Otherwise, other eclipses handed down by the tradition of one's own school might be computed. In the light of these and of the eclipses actually observed by oneself, future eclipses should be computed and forecast. Or, eclipses occurring at other parts of the country should be computed using the longitude, latitude, etc., of that part of the country and, with that as basis, the true Sun, Moon and Node, (at the relevant times) ascertained. Then, from the Sun, Moon and Node, ascertained (as

above), past and future eclipses at one's own place shall be computed, using the latitude and longitude of one's own place[52].

Nīlakaṇṭha follows up the above instruction with the details of a number of eclipses observed and recorded by Parameśvara, his grand-teacher, in the *Siddhāntadīpikā*[53] (32-35).

At the close of enumeration of the eclipses, Nīlakaṇṭha indicates the procedure for verification. He says:

The computation of the Mean planets having been enunciated by Parameśvara later than Śrīpati, the former will tally (better) with observation. Therefore, in the case of the eclipses enumerated by Parameśvara, those observed by me (Nīlakaṇṭha) and others that might be mentioned hereafter, the Mean Sun etc., shall be computed as directed by Parameśvara. Their True positions shall (however) be computed according to Śrīpati's method. The eclipses should then be computed duly making use of the methods derived from the rationales enunciated by me (in my *Bhāṣya* on the *Kālakriyā* and *Golapāda*s (of the *Āryabhaṭīya*)[54].

Nīlakaṇṭha then illustrates his instructions by means of a practical example (pp.35-36). The precession of the equinoxes which has also a bearing on the results is also touched upon here (pp.36-37).

h. True Motion, Position, etc., of planets

While continuing the previous computation, the rationale underlying the determination of the true motion of a planet at a particular place at a particular moment is explained in detail. Examples are also worked out for true Sun and Moon to illustrate the rationale of the *dvitīya-sphuṭa* of planets (pp.37-41). Another topic treated in a similar manner relates to the correction of the periphery of the *manda* epicycle by means of the *natajyā* (Rsine zenith distance) (pp.42-44). Other corrections to be applied to get the true planet, such as *ayanacalana* (precession of the equinoxes), *prāṇakālāntara* and *caradala* (half ascensional difference), are also set out in turn with the tables of the Rsines of the latter two and the method of application thereof (pp.44-49).

i. Relation of the sides and hypotenuse

After explaining the rationale involved in determining the height of a lamp-post by means of two gnomons (pp.49-50), Nīlakaṇṭha rationalizes, from fundamentals, the graphical proofs for the relation between the sides and hypotenuse of a right angled triangle – the Pythagoras theorem. The discussion is, however, incomplete, the manuscripts having a long break here (p.50).

j. Reduction of angular distances

Errors in results arise on account of the observer being stationed on the Earth's surface, while the basic measures relate to the centre of the Earth sphere or to the horizontal plane thereof. These are corrected by reducing the basic angular distances to the *dṛggola* ('visible celestial sphere'). Nīlakaṇṭha rationalizes this type of correction with reference to the orb of the Moon (pp.51-52).

Conversely, in the case of the gnomonic shadow, it is the measure on the *dṛggola* that needs to be reduced to that of the *bhagola* ('sphere of the zodiac'). The rationalization of the processes involved forms the last section in the present manuscript, which breaks off half-way during the middle of the said discussion (pp.53-55).

The only available manuscript of *Jyotirmīmāṃsā* is incomplete, its beginning and end being lost, and some gaps occur in the middle. However, the nature of the work and the manner in which its author Nīlakaṇṭha is presenting it could give one some idea of the portions lost.

k. The beginning of the work

In the original palmleaf manuscript,[55] the *Jyotirmīmāṃsā* is inscribed in continuation of another work of Nīlakaṇṭha, being the *Siddhāntadarpaṇa* with auto-commentary. In this manuscript, the final portion of *Siddhāntadarpaṇa* [56] along with the initial portion of *Jyotirmīmāṃsā* is lost, the lost in the latter work being presumably, not more than one folio.

A cue for the missing portion could be had from the tenor of the first section of the work (see below, pp.1-2), where it is established

that appropriate corrections based on observation should be applied periodically to astronomical parameters etc., so that they might give results which would tally with observation. The available manuscript commences with arguments based on eclipses supporting the said thesis, introduced with the words *atha grahaṇam*. It may be presumed reasonably that the author must have, earlier to this, presented similar arguments to the same purpose, based on other visible astronomical phenomena like the setting of the planets, the heliacal rising of the signs, gnomonic shadow etc., with the introductory words, *atha mauḍhyam, atha lagnam, atha chāyā* etc.

Besides the above, the lost portion should have contained one or more introductory verses through which the author would have uttered the usual invocation to his favorite deity and stated his purpose in composing the work.

l. Missing portions in the middle

Apart from the minor gaps, with which the manuscript abounds and which have mostly been gilled tentatively, there occur in the manuscript at least three major omissions which could, obviously, not be filled and, which therefore, mar the continuity of reading, The first of these occurs towards the end (?) of section 14, on 'Astronomical corrections through eclipses', where an illustrative eclipse was being computed (p.37). The second omission occurs towards the beginning of section 19, on the 'Height of a lamp post by means of two gnomons', the close of the previous section also having been lost (p.49). A portion towards the close of section 20 and beginning of section 21 is also lost.

m. Omission at the end

The extant manuscript breaks off abruptly towards the middle of section 22, being a discussion on the reduction of the minutes of arc of the visible celestial sphere (*dṛggola*) to those of the zodical sphere (*bhagola*). There is no possibility of knowing, with exactitude, what more Nīlakaṇṭha had intended to include in the work. The comprehensive title *Jyotirmīmāṃsā* given to the work and of

Nīlakaṇṭha's apparent intention (1) to demonstrate that the discipline of *Jyotiṣa* is based on observation, and (2) to study the comparative accuracy of the different systems, would induce one to presume that the work contained all that is conveyed by the title and covered by the said intentions. Thus, after completeing the topic at hand viz., *Grahasphuṭa* (True positions of planets), Nīlakaṇṭha should have taken up for investigation other subjects like *Lagna* (Rising point of the ecliptic), *Chāyā* and *Viparītacchāyā* (Shadow and Inverse shadow), and *Candraśṛṅgonnati* (Elevation of the Moon's horns).

The school of Nīlakaṇṭha

An important work based on *Tantrasaṅgraha* is the *Yuktibhāṣā*, 'Rationale in the Malayalam language', whose sole aim is to rationalize the theories involved in the constants and computations occurring in the *Tantrasaṅgraha*. Thus, after the benedictory verses, the work commences with the statement:

aviṭe naṭe tantrasaṅgrahatte anusariccu grahagatiyinkal upayogamuḷḷa gaṇitaṅṅale muzhuvanāyi colluvān tuṭaṅṅunneṭattu...

'Here, commencing an elucidation in full of the rationales of planetary computations according to the *Tantrasaṅgraha* ...'

The work finds its first reference in modern writings in an article by C.M. Whish in 1835, where it is referred to for verifying the date of the author of *Tantrasaṅgraha*. Whish had contemplated "a farther (sic) account of the *Yuktibhāṣā*... will be given in a separate paper," which, however, does not appear to have been written or published.

Yuktibhāṣā, known also as *Gaṇitanyāyasaṅgraha*, 'Compendium of astronomical rationale', has been a popular text in Kerala for more than four hundred years, since its composition towards AD. 1530. Several manuscripts of the work are known. However, since the work is couched in Malayalam language, which is spoken only in Kerala it has remained practically, beyond the purview of scholars who did not know the language, in spite of its having been published. And the few articles on this important work relate to only certain individual

topics treated herein. It is therefore necessary that a critical appraisal of the nature and contents of this work as a whole is made, so as to enable scholars take up the same for further study.

The introductory verses of the *Yuktibhāṣā* do not mention the name of its author, nor do its manuscripts indicate his name at their closing colophons. There are, however, evidences which point to the correct name of the author of *Yuktibhāṣā* as Jyeṣṭhadeva and his date to be AD 1500-1610.[57]

The astronomical chronology (*granthavari*) in Kerala continued uninterrupted. The post colophonic statement in the Malayalam language found in an old palmleaf manuscript of a Malayalam commentary on *Sūryasiddhāntha* preserved in the Oriental Institute, Baroda, Ms. No, 9886, proves the fact.[58]

Conclusion

The account of Nīlakaṇṭha Somayāji and his work as depicted above is a pointer not only to the work in the field of astronomy done by him, but also to the development of this discipline in this period in India.

FOOTNOTES:

1. *Āryabhaṭīya*, *Trivandrum Sanskrit Series* (*TSS.*), No.101 (Trivandrum, 1930), pp. 1-180.
2. The term *Gārgya* is often affixed to his name in references.
3. Ed. P.R. Menon, *Tuncattu Granthāvali*, No.3 Tuncattu Karyalayam, Chittoor, 2nd edn., 1931.
4. Vide P.R. Menon in his article '*Tuncattu Ezhuttacchan*' in the Malayalam monthly, Tuncattu Ezuttacchan, 3 (1952-53) 127-35.
5. Ibid. This stotra is published in a collection of stotras in Malayalam script entitled *Stavaratnamālā*, Pt. I.

6. It may be noted that in the expression Gārgya Kerala prefixed to the author's name, the word Kerala referes to the name of his house and not to the state, as is sometimes taken.
7. *Cf.*, Vaṭakkumkūr Rājarāja Varma, *History of Sans. Lit. in Kerala*, Vol. I, Trivandrum, 1938, p.384.
8. *Āryabhaṭīya*, *TSS*. No.101 (Trivandrum, 1930), p.156.
9. *Āryabhaṭīya*, *TSS*. No. 185 (Trivandrum, 1957), p. 156.
10. *Āryabhaṭīya*, *TSS*. *No.* 101 Rpt. 152. (Trivandrum, 1977), p. 85.
11. *Ibid.*, p. 62.
12. *Āryabhaṭīya*, *TSS*. No. 101 (Trivandrum, 1977), p. 152.
13. *Ibid.*, p.208.
14. Even with regard to Nīlakaṇṭha's *Tantrasaṅgraha*, its introductory verse,

    हे विष्णो निहितं कृत्स्नं जगत् त्वय्येव कारणे।
    ज्योतिषां ज्योतिषे तस्मै नमो नारायणाय ते ।। has a veiled reference to his patron (Netra) Nārāyaṇa at whose instance that work too seems to have been written.
15. *Āryabhaṭīya*, *TSS*. No. 101 Rpt. (Trivandrum, 1977), p. 241.
16. Ulloor, *Kerala Sāhitya Caritram*, Vol.II, Trivandrum (1954), p.114. For a manuscript of this work see Kerala Uni. Mss. Lib., No. 3336-B.
17. *Cf.* the detailed colophon quoted above.
18. *Āryabhaṭīya*, *TSS*. No. 110 Rpt. (Trivandrum, 1977), p. 63.
19. *Siddhāntadarpaṇavyākhyā*, on verse 27, p. 30.
20. *Ibid.*, under verse 18.
21. *Āryabhaṭīyabhāṣya*, *Golapāda*, verse 3.
22. *Tantrasaṅgraha*, verse 1, refer to fn. 37.

23. These correspond in the Gregorian calendar to March 22, 1500 and March 27, 1500 A.D. respectively.

24. *Siddhāntadarpaṇa*, verse 18, refer to fn. 35.

25. *Āryabhaṭīya, TSS. No. 101 & 110 Rpt. (Trivandrum, 1977), p.* 208.

26. *Cf.*, *Āryabhaṭīyabhāṣya, TSS.* No. 101, pp. 53, 158, where Parthasarathi Misra's *Vyāptinirṇaya* and *Advaitavivaraṇa* and *Ajitā* (commentary on *Ślokavārttika*) and its commentary *Vijayā* come in for quotation. On *Golapāda*, 50, the *Bṛhhaṭṭīkā* of Kumārila Bhaṭṭa is cited.

27. *Cf.*, quotations from the *Vākyapadīya*, *Āryabhaṭīyabhāṣya*, *TSS.*. No. 110 Rpt. (Trivandrum, 1977), p. 31.

28. See *Āyabhaṭīyabhāṣya*, *TSS.* No.101 Rpt. (Trivandrum, 1977), p. 241.

29. See commentary on *Siddhāntadarpaṇa*, verses 1,3; the *Grahaṇa* work, pp. 48, 49: and *Āryabhaṭīyabhāṣya*, *Golapāda*, verse 48, where the *Taittirīya Āraṇyaka*, *Ṛgveda*, *Parāśarasmṛti*, *Kālanirṇaya* of Sāyaṇa, Manusmṛti etc. are quoted.

30. See *Siddhāntadarpaṇa-vyākhyā*, p.1 refer to fn.35.

31. *Cf.*, *Āryabhaṭīyabhāṣya*, *TSS.*. No.110 Rpt. (Trivandrum, 1977), pp. 16.26.

32. *Cf.*, *ibid.*, p.8.

33. On this Mādhava (c.1340-1425), who was a teacher of Parameśvara, see the present writer's introduction to Mādhava's *Veṇvāroha* (Tripunnithura, Cochin, 1957), and *Sphuṭacandrāpti* (Hoshiarpur, 1973).

34. Critically ed. with Introduction by K.V. Sarma, Vishveshvaranand Institute, Punjab University, Hoshiarpur, 1970.

35. Critically ed. with the author's own commentary and Translation and two Appendices and detailed Introduction by K.V. Sarma, Vishveshvaranand Institute, Punjab University, Hoshiarpur, 1976.

36. Cr. Ed. with Auto-commentary, Introduction and two Appendices by K.V. Sarma, Vishveshvaranand Institute, Hoshiarpur, 1976.

37. Cr. Edited with two commentaries, *Yuktidīpikā* and *Laghuvivṛti*, and detailed Introduction and Indices by K.V. Sarma, Vishveshvaranand Institute, Punjab University, Hoshiarpur, 1977.

38. Ed. in 3 volumes, *TSS.*. Nos. 101, 110, 185 (Trivandrum, 1930, 1931, 1957).

39. See *Āryabhaṭīyabhāṣya*, *TSS.* No. Rpt. (Trivandrum, 1977), p. 101.

40. *Ibid.*, p. 156.

41. *Ibid.*, p.1.

42. See *Āryabhaṭīyabhāṣya*, *TSS.* No..185 (Trivandrum, 1957), p.102.

43. In Chapter IV, verse 27, *TSS.*. No. 188, p.107.

44. Cr. Ed. with Introduction and Appendices by T.S. Kuppanna Sastri and K.V. Sarma, K.S. Research Inst., Madras, 1964.

45. *Ibid.*, p. 119.

46. See *Āryabhaṭīyabhāṣya*, *TSS.* No. 185 (Trivandrum, 1957), p.149.

47. Published by the Astrological Research Institute, Bombay-25, 1950.

48. See *Āryabhaṭīyabhāṣya*, *TSS.* No. 185 (Trivandrum, 1957) pp. 132-49.

49. Ed. with Introduction and Appendices, by K.V. Sarma. Vishveshvaranand Institute, Punjab University, Hoshiarpur, 1977.

50. गणितोन्नीतस्य चन्द्रादेः देशविशेषान्वयस्य प्रत्यक्षेण संवादः, ततो निश्चितान्वयस्य परस्य गणितलिंगोपदेशः, ततस्तस्याप्तोपदेशावगतान्वयस्य अनुमानं, संवादः, परस्मै चोपदेशः इति सम्प्रदायाविच्छेदात् प्रामाण्यम्।

51. पञ्चसिद्धान्तस्तावत् क्वचित्काले प्रमाणमेव इत्यवगन्तव्यम्। अपि च यः सिद्धान्तो दर्शनाविसंवादी भवति सोऽन्वेषणीयः। दर्शनसंवादश्च तदानीन्तनैः परीक्षकैः ग्रहणादौ विज्ञातव्यः। ये पुनरन्यथा, प्राक्तनसिद्धान्तस्य भेदे सति यन्त्रैः परीक्ष्य ग्रहाणां भगणादिसंख्यां ज्ञात्वा अभिनवसिद्धान्तः प्रणेय इत्यर्थात्, तत् त इहलोकेऽहसनीयाः, परलोकेऽदण्डनीयाश्च इति।

52. अथ सिद्धान्तदीपिकायाम् उदाहृतानि ग्रहणानि परीक्षमाणेन गण्यानि। अन्यानि वा ऐतिह्यसिद्धानि स्ववंश्यैरुपदिष्टानि गण्यन्ताम्। एतैः प्रत्यक्षावगतैश्च अनागतग्रहणं निर्णीय वक्तव्यम्। जनपदान्तरजात् तद्देशान्तराक्षादिभिः गणयित्वा रवीन्दुतुंगपातान् विज्ञाय अतीतमनागतं स्वदेशजं ग्रहणं स्वदेशान्तराक्षाभ्यां विज्ञातैस्तैरेवं ग्रहोच्चपातैर्गणयित्वा निर्णयाः।

53. See *Siddhāntadīpikā*, the supercommentary of Parameśvara on Govindasvāmi's *Bhāṣya* on the *Mahābhāsakrīya* of Bhāskara, under verse 5.77 (Ed. by T.S.K Sastri, Madras, 1957, pp. 329-32).

54. सिद्धान्तशेखराद्युक्तमध्यमेभ्यः परमेश्वरोक्तानां नूतनत्वाद् अस्य दृष्टिसाम्यं स्यात्। तस्मात् सिद्धन्तदीपिकोदाहृतानि अस्माभिः (नीलकण्ठेन) दृष्टानि च तत्तदवसरे वक्ष्यमाणानि परमेश्वरोक्तप्रकारेण १. अर्कादिमध्यमान्यानीय श्रीपत्युक्तप्रकारेण स्फुटीकृत्य कालक्रियागोलपादोक्ताभिः अस्माभिर्व्याख्याताभिः युक्तिभिः सिद्धैः क्रियाविशेषैश्च गण्यन्ताम्।

55. Ms. no. p. 975 of the Trivandrum Palace Collection, now deposited in the Kerala Univ. Or. Res. Inst. and Ms. Library.

56. This lost portion contains the last five verses, 28 to 32, of the work and the commentary thereon, vide, edn. of *Siddhāntadarpaṇa* with auto-commentary, by K.V. Sarma, Hoshiarpur, 1976, p.31.

57. For detailed reference on the topic see the article *Gaṇitayuktibhāṣā of Jyeṣṭhadeva.*

58. See Teacher - Pupil tradition in the article *Āryabhaṭa and Āryabhaṭan Astronomy: Antecendents, Status and Development.*

JYOTIRMĪMĀṂSĀ OF NĪLAKAṆṬHA SOMAYĀJĪ AND THE TRADITION OF REVISION IN HINDU ASTRONOMY*

Jyotirmīmāṃsā ('Investigations on astronomical rationale') by Nīlakaṇṭha Somayājī (A.D. 1444-1545),[1] is a unique work in Hindu astronomy, where in the author deals with the discipline not as one of mere computation, but also of experimentation and observation. Nīlakaṇṭha was an astute astronomer of Kerala in South India and was the author of a dozen works, all on astronomy, both original works and commentaries,[2] his *magnum opus* being an elaborate *Bhāṣya* on the *Āryabhaṭīya*.[3]

In the *Jyotirmīmāṃsā* of Nīlakaṇṭha insists that results arrived at by computation should accord with those of observation. He adds that when texts were actually composed, computations made using the parameters given in those texts accorded with observation. When, however, on account of the passage of time, the two results differed, necessary corrections have to be applied suitably to the parameters so that computations made using the revised parameters accorded with observation. Thus he writes:

"Atha grahaṇam. nanv evam api svakāla eva gītikokta-bhagaṇādyāḥ (Āryabhaṭīyam, Gaṇitapāda, 3 ff.) (sūkṣmaḥ, yadā) gītasya grahaṇasya pratyakṣasaṃvādaḥ syāt, yata idānīṃ granthakaraṇakāle tṛtīye divyābde mahān khalu bheda upalabhyate. gaṇitānītakālataḥ paścād eva hīdānīṃ sarvāṇy api grahaṇāni dṛśyante."

(*Jyotirmīmāṃsā*, p. 1).

'Now, eclipse. The revolutions of planets as enunciated in the *Gītikā* (section of the *Āryabhaṭīya*, 3 ff.) should have been true for contemporary times when eclipses as computed were identical with

Oriental Journal, S.V. University, Tirupati, Vol. 27. 1984.

what was observed. At the present time, being the third divine year when this work has been composed, there is found considerable differences. Now-a-days, eclipses are all seen to occur only after their times arrived at by computation.'

Nīlakaṇṭha illustrates his statement by two eclipses which he had observed, the latter of which might be noticed here: '*sambhuñjītāhistapanam*' (16,86,847) *ity asminn ahargaṇe sparśopalabdhā padacchāyā ekādaśasaṅkhyā. mokṣadyugatam punaḥ pañcadaśa ghaṭikāḥ aṣṭāṃśatrayasahitāḥ I tac ca hariharādiṣu madhyatamaskam I tasmin dine 'pi gītikoktabhagaṇādisiddha-candrādibhir gaṇyamāne grahaṇaṃ naivātra syāt* (*op. cit.* p. 2).

'On *Kali* date 16, 86, 847 the gnomonic shadow at the time of commencement (of an eclipse) was eleven. The residual time for sunset was 15 *ghaṭikās* and 24 *vighaṭikās*. In places like Harihara (in Karnataka), it was mid-eclipse then. On that day (in his place) there should have been no eclipse at all if computed with the revolution numbers enunciated in the *Gītikā*.'

The author now points out that Āryabhaṭa had made a provision for such contingencies. He says:

'*evam ādidūṣaṇam parair udbhāvyamānam parihartum parīkṣāprakāram āha, yadartham padatrayeṇa sakalā yuktayaḥ pradarśitāḥ* '

kṣitir aviyogāt dinakṛt ravīnduyogāt prasādhitaś cenduḥ I
śaśitārāgrahayogāt tathaiva tārāgrahās sarve II

(*Āryabhaṭīyam Golapāda,* 48)

Iti atroktābhiḥ uktibhir eva buddhimadbhiḥ samyak parīkṣaṇaṃ śakyaṃ kartum (op. cit. p. 2).

It is to ward of possible objections of this nature that could be raised by others, that (Āryabhaṭa) enunciated the method of experimentation with the words: 'The Sun (can be obtained) from the conjunction of the Earth and the Sun, the Moon from the conjunction

of the Sun and the Moon, and all the other planets from the conjunction of the (respective) planets and the Moon. 'By means of the methods enunciated here, it is possible for the intelligent to conduct the necessary experiments.'

But there could arise the doubt whether divine revolution said to have been recorded would go wrong at all. Nīlakaṇṭha envisages this objection thus:

"nanu tapobhiḥ prasanno brahmā āryabhaṭāya bhagaṇa-paridhyādikaṃ grahagaṇanasādhanabhūtaṃ saṅkhyāviśeṣam upadideśa. tad upadiṣṭam punar āryabhaṭaḥ sarvam yathopadiṣṭam eva daśabhirgītibhir nibabandha iti kecin manyante / tasya kutaḥ parīkṣaṇam, brahmaṇaḥ sarvajñatvāt, rāgadveṣābhāvāc ca, avitathaniścayāt, iti cet" (*Jyotirmīmāṃsā*, p. 2).

'Some might argue that God Brahmā, being pleased by the penances (of Āryabhaṭa), taught him the specific planetary revolution numbers to be used in the computation of eclipses. And, Āryabhaṭa depicted in ten *gīti* verses all that he was instructed. Why then should there be any verification in that matter, for Brahmā is all - knowing, not vitiated by likes and dislikes and therefore positively truthful.'

Nīlakaṇṭha's reply is characteristic of a logical scientist. He says, 'O dull-head! That is not so. Then blessings of a supernatural being would only be in the form of cleansing the intellect and inspiriing it. To be sure, God Brahmā or the Sun will not come down in person and instruct (a person).'

manda! maivam. devatāprasādo mativaimalyahetur eva / na ca punaḥ brahmā ādityo vā svayam evāgatya upadiśet /

Nīlakaṇṭha continuous :

evam eva vakṣyati cānantarasūtre sad-asaj-jñānasamudrāt samuddhṛtaṃ devatāprasādena / saj-jñānottamaratnam mayā nimagnaṃ svamatinā vā //

(*Āryabhaṭīyam, Golapāda*, 49)

Moreover, he (Āryabhaṭa) himself says in the next verse: 'By the grace of Brahmā, the precious jewel of excellent knowledge (of astronomy) has been brought out by me by means of the boat of my intellect from the sea of true and false knowledge, by diving deep into it.'

na punaḥ brahmopadiṣṭam sad-asaj-jñānasamudranimagnam. na ca tatra saṅkīrṇatā / sad asajjñānayoḥ asajjñānam anādāya svamatinā vā sajjñānasyaiva uttamaratnasya uddharaṇam upapadyate / tasmād brahmaṇopadiṣṭam ity etad āryabhaṭīyavākye naiva viruddham /
(op.cit. p.2*).*

In order to reinforce the argument of experimentation, Nīlakaṇṭha takes the aid of the forensic discipline of *Mīmāṃsā*. He says: *Jyotiśśāstre 'pi yugaparivṛttiparimāṇadvāreṇa candrādityādi-gativibhāgena tithinakṣatrajñānam avicchinna-sampradāya-gaṇitānumānamūlam' iti vārttikakāro 'pi grahagatijñānam anumānenāha / (Tantravārttika* on *Mīmāṃsāsūtra 1.3.2). tatrā-vicchinnasampradāyam apy evam vyācaṣṭe- 'gaṇitonnītasya candrādeḥ deśaviśeṣānvayasya pratyakṣeṇa saṃvādaḥ, tato niścitānvayasya parasya gaṇitaliṅgopadeśaḥ, tatas tasyāptopadeśāvagatānvayasya anumānam, saṃvādaḥ, parasmai copadeśaḥ, iti sampradāyāvicchedāt prāmāṇyam iti / (Ajitāvyākhyā, by Paritoṣamiśra).*

'The Vārttikakāra (Kumārila Bhaṭṭa) has observed that the knowledge of the lunar days and constellations based on planetary revolutions and derived by unbroken computational tradition is based on inference. The expression 'unbroken tradition' is explained thus: The computed Moon is first correlated with the observed Moon at a particular place. Then instruction of the reasons for the computational difference to another, (a pupil), who clearly understands the matter. Then inference (by the pupil) who has been so instructed by the reliable person (viz., his teacher). Then verification and later instructions (in a similar manner, by the pupil) to another (viz., his pupil). The authoritativeness is due to this type of unbroken continuity.'

Therefore, Nīlakaṇṭha asserts: Experiments should be (continued to be) performed by all (astronomers) in the teacher-disciple

tradition. *Tasmāt śiṣyapraśiṣyaparamparayā sarvair api parīkṣaṇaṃ kāryam* I (*Jyotirmīmāṃsā*, p. 4).

Elsewhere Nīlakaṇṭha asserts that even a new system of astronomy might be enunciated if there be need for it. Thus, in a later section of the *Jyotirmīmāṃsā* he pointed his finger towards certain doubting Thomases, who despair saying: 'There are current astronomical *siddhāntas*, like the *Paitāmaha* and others which do not tally mutually. There will be differences in time (in *nāḍikās* and *vināḍikās*) for the same moment of time if computed by these different *Siddhāntas.* When there is difference in time indicated, Vedic, domestic and worldly rituals, which are dependent on their performance at correct times become infructuous. And, when there is defect in rituals, worldly life breaks up. Alas. 'We have fallen into a calamitous situation' (op. cit. p. 6):

nanu paitāmahādibhedena parasparaviruddhāś ca siddhāntā bhavanti I siddhāntabhede sati kālabhedaḥ I kālabhede sati kālāṅgāni śrauta-smārta-laukikāni karmāṇi vikalāni syuḥ I karmavaikalye sati lokayātrocchedaḥ I hā ! dhik ! saṅkaṭe mahati patitās smaḥ I (*op. cit.* p. 6).

The reaction of Nīlakaṇṭha to this apparently insurmountable objection is clear and decisive. He says:

'"atrocyate - 'ṛjumate' sa na śocitavyaḥ. Gurucaraṇa-paricaraṇaparaiḥ kim iva na jñāyate I pañcasiddhāntās tāvat kvacitkāle pramāṇam eva ity avagantavyam I api ca yaḥ siddhānto darśanāvisaṃvādī so 'nveṣaṇīyaḥ I darśanasaṃvādaś ca tadānīntanaiḥ parīkṣakair grahaṇādau vijñātavyaḥ I ye punar anyathā prāktanaSiddhāntasya bhede sati, yantraiḥ parīkṣya grahāṇāṃ bhagaṇādisaṅkhyāṃ jñātvābhinavasiddhāntaḥ praṇeya ity arthāt I tat ta ihaloke ' hasanīyaḥ, paraloke' daṇḍaniyaś ca iti" (op. cit., p. 6*).*

'Here, I say: Oh simpleton ! The situation is not to be despaired of. It is to be noted that for a certain period (only) the Five *Siddhānta*s will remain authoritative. Now, one has to look for a system which gives results identical with observation. Indentity in observation should

be tested by contemporary astronomers at the time of eclipses. In the case of those (*Siddhāntas*) that differ, in other words, when there is difference in an early *Siddhānta* (which is being tested), the revolution numbers of the planets (according to that *Siddhānta* should be revised using machines, and a new *Siddhānta* should be enunciated. For this (act) one will not be laughed at in this world nor will one be punished in the world after (death).'

One does not meet with categorical statements in early texts, though the practice of the priniciple stated above had all along been there in Hindu astronomy.

REFERENCES:

1. *Jyotirmīmāṃsā,* ed. with introduction and appendices by K. V. Sarma, Vishveshvaranand Institute, Hoshiarpur, 1977.
2. On the life and works of Nīlakaṇṭha, see *op. cit.* Introduction, pp. xxvii-xxxviii.
3. *Āryabhaṭīya* Edited in three volumes, *Trivandrum Sanskrit Series*, Nos. 101, 110, 185 (1930, 1931, 1935); also *Āryabhaṭīya* with trans. and notes, ed. by K.V. Sarma & K.S.Sukla, Indian National Science Acadamy, New Delhi, 1976.

GAṆITA -YUKTIBHĀṢĀ OF JYEṢṬHADEVA:

A Book of Rationales in Indian Mathematics and Astronomy : An Analytical Appraisal*

During medieval times there had occurred in Kerala a spurt of activity in the mathematical and astronomical studies. What is particularly significant herein is that some of the works produced related to *Yuktis* and *Upapattis,* i.e. rationales and proofs. For this reason, these texts flash a torch, as it were, in the dark areas of Indian mathematics and astronomy and enable us to understand how these scientists designed methodologies and derived formulae, the application of which produced reliable results.

One of the important texts of this type is the *Gaṇita-yuktibhāṣā* of Jyeṣṭhadeva (1500-1610). Since the work has been composed in the local language of Kerala, *viz.,* Malayalam, it has, by and large, remained beyond the ken of scholars not knowing that language, with the result that there have been but sporadic studies and that too only on certain topics dealt with therein. An attempt is made in this paper to give an idea of the contents of the work, drawing attention to certain peculiarities therein, towards making a detailed study thereof. The question of its authorship and date has also been tackled.

The work, is divided into two parts, with 17 chapters in all.* The first part is related to the depiction of the rationales of Arithmetic, Algebra, Geometry and Trigonometry, and the second part to Astronomy. The seven chapters of Part I deal with: I. Logistics, II. Ten Algebraic problems, III. Fractions. IV. Rule of Three, V. *Kuṭṭākāra.* VI. Circle, and VII. Disquisition on R-Sine. Part II deals with: Ch. VIII. Planetary motion, IX. Celestial sphere, X. Declination and Right Ascension, XI. Fifteen Problems in Right Ascension, Declination etc., XII. Directions and Shadow, XIII. Ten Problems on Spherical Triangles, XIV. *Lagna and Kālalagna,* XV. Eclipses and Parallax Corrections, XVI. *Vyatīpāta,* and XVII. *Dṛkkarma* or Reduction to observation, and the phases of the Moon.

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Introduction

During medieval times, there had been in Kerala, in the southern-most part of India, an effusion of mathematical and astronomical investigations, at least a substantial part of which has been documented in original works, commentaries and minor tracts devoted solely or primarily to the elucidation of theories and rationales of computation.[1] An important work among these is the *Gaṇita-yuktibhāṣā* (*GYB*), 'Rationale in the Malayalam language', whose sole aim is to rationalize the theories involved in the constants and computations occurring in the *Tantrasaṅgraha,* an important astronomical work of Nīlakaṇṭha Somayāji (A.D. 1443-1545).[2] Thus, after the benedictory verses, the work commences with the statement:

'*aviṭe naṭe trantrasaṅgrahatte anusariccu grahagatiyiṅkal upayōgamuḷḷa gaṇitaṅṅaḷe muzhuvanāyi colluvān tuṭaṅṅunneṭattu...*'

'Here, commencing an elucidation in full of the rationales of planetary computations according to the *Tantrasaṅgraha...*'

The work finds its first reference in modern writings in an article by C. M. Whish in 1835,[3] where it is referred to towards verifying the date of the author of *Tantrasaṅgraha.*[4] Whish had contemplated 'a farther (sic) account of the Yucti-Bhasha... will be given in a separate paper,' which, however, does not appear to have been written or published.[5]

Yuktibhāṣā, known also as *Gaṇitanyāyasaṅgraha* 'Compendium of astronomical rationale', has been a popular text in Kerala for more than four hundred years, since its composition towards A.D. 1530. Several manuscripts of the work are known.[6] However, since the work is couched in the Malayalam language which is spoken only in Kerala it has remained, practically, beyond the purview of scholars who did not know the language, in spite of its having been published.[7] And the few articles on this important work relate to only certain individual topics treated herein.[8] It is therefore necessary that a critical appraisal of the nature and contents of this work as a whole is made, so as to enable scholars take up the same for further study.

Authorship of *Gaṇita-Yuktibhāṣā*

The introductory verses of the *GYB* do not mention the name of its author, nor do its manuscripts indicate his name at their closing colophons. However, one of its manuscripts preserved in the Sanskrit College Library, Tripunithura which had been used by Rama Varma Maru Thampuran for his edition of the work, had at its close the verse:

alekhi yuktibhāṣā vipreṇa brahmadattasaṃjñena I
'ye golapathasthās syuḥ' kalirahitāḥ śodhayantas te II

Taking the word *alekhi* in the verse to mean 'composed' instead of its natural meaning 'written, copied', the Introduction to the said edition took Brahmadatta mentioned in the verse as the author, and the date given by the *Kali* chronogram *ye golapathasthās syuḥ* corresponding to A.D. 1750, as the date of its composition.[9]

There are, however, evidences which point to the correct name of the author of *Gaṇita-yuktibhāṣā* as Jyeṣṭhadeva and his date to be A.D. 1500-1610. Thus, an old palmleaf manuscript, No. 755, of the Kerala University Manuscripts Library, entitled *Gaṇitayuktayaḥ* contains many astronomical tracts, in one of which, dealing with the precession of the equinoxes (*ayanacalana*), occurs the statement:

Atha vikṣepacalanasyānītau pūrvasūribhiḥ I
proktā ye matabhedās tān vakṣye tattvabubhutsayā II

* * * * *

jūkakriyādike pāte svarṇam tatsāyane vidhau I
ity uktā kṣepacalanasyānītis tantrasaṅgrahe I
jyeṣṭhadevo 'pi bhāṣāyām nādhikam kiñcid uktavān II

The *Tantrasaṅgraha* referred to here is, obviously, the work of Nīlakaṇṭha Somayāji, and the *Bhāṣā* specified as the work of Jyeṣṭhadeva is the *Yuktibhāṣā,* which, as indicated above, seeks to set out and elucidate the theories and practices involved in the *Tantrasaṅgraha.*

There are more clear evidences which point to the correct name of the author of *Yuktibhāṣā* as Jyeṣṭhadeva and his date to be A.D. 1500-1610. Thus, an astronomical chronology (*granthavari*) in the Malayalam language found as a post-colophonic statement in an old palmleaf manuscript of a Malayalam commentary on *Sūryasiddhānta* preserved in the Oriental Institute, Baroda. Ms. No. 9886, contains in it the statements:

parameśvaran vaṭaśśeri nampūri, nilāyāḥ saumyatīrasthaḥ parameśvaraḥ...asya tanayo dāmodaraḥ, asya śiṣyo nīlakaṇṭhasomayāji, iddeham tantrasaṅgraham, āryabhaṭīyabhāṣyam mutalāya granthaṅṅaḷku karttāvākunnu. 'lakṣmīśa-nihita-dhyānaiḥ' iti asya kalinā kālanirṇayaḥ I

'*pūrvokta-dāmodarasya śiṣyaḥ jyeṣṭhadevaḥ, iddeham paraṅṅoṭṭu nampūriyākunnu yuktibhāṣā-granthatte uṇṭākkiyatum iddeham tanne*'

'*jyeṣṭhadevante śiṣyan tṛkkaṇṭiyūru acyuta-piṣāraṭi, iddeham sphuṭanirṇayam, goladīpikā mutalāya grantha (ṅṅaḷkku) karttāvākunnu*'.

'*acyuta-piṣāraṭiyuṭe śiṣyan melputtūru nārāyaṇa bhaṭṭatiri, iddeham nārāyaṇīyam, (prakriyā) sarvasvam mutalāya granthaṅṅaḷkku kartā. 'āyur-ārogya-saukhyam' ityādi-kalinā.kālanirṇayaḥ....*'

Parameśvara was a Nampūri from *Vaṭaśśeri* (family). He resided on the northern bank of the Nilā (river)...His son was Dāmodara. Nīlakaṇṭha Somayāji was his pupil. He, (the latter), is the author of the *Tantrasaṅgraha, Āryabhaṭīyabhāṣya* and other works. His date is determined by the *Kali* days 16, 80, 553 (A.D. 1500).

Jyeṣṭhadeva was the pupil of the above Dāmodara. He was a *Nampūtri* from *Paraṅṅoṭṭu* (family)[10]. He is also the author of the work *Yuktibhāṣā*. 'Acyuta Piṣāraṭi of Tṛkkaṇṭiyūr was the pupil of the Jyeṣṭhedeva. He is the author of the *Sphuṭanirṇaya, Goladīpikā* and other works.

'Melputtūr Nārāyaṇa Bhaṭṭatiri was the pupil of Acyuta Piṣātaṭi. He is the author of the *Nārāyaṇīya, (Prakriyā) Sarvasva* and other works. His date is determined by the *Kali* days 17, 12, 210 (A.D. 1587).'

Here, it is specifically stated that Jyeṣṭhadeva is the author of *Yuktibhāṣā* and the teacher-pupil succession is: Parameśvara (A.D. 1360-1455) - son, Dāmodara - pupils, Nīlakaṇṭha Somayāji (1443-1545) and Jyeṣṭhadeva (1500-1610 *c.*) - pupil, Acyuta Piṣāraṭi (1550-1621) - pupil, Nārāyaṇa Bhaṭṭatiri (A.D. 1587).

That Jyeṣṭhadeva was the teacher of Acyuta Piṣāraṭi is stated by Piṣāraṭi himself in the concluding verse of his work on the computation of eclipses, entitled *Uparāgakriyākrama:*

> '*proktaḥ pravayaso dhyānāt*' *jyeṣṭhadevasya sadguroḥ* I
> *vicyutāśeṣadoṣeṇetyacyutena kriyākramaḥ* II

'Thus has been stated the (*Uparāga*) - *Kriyākramaḥ* by Acyuta of clear thought through his contemplation of (the teachings of) his aged benign teacher Jyeṣṭhadeva'. The Malayalam commentary to *Uparāgakriyākrama* explains that the expression *proktaḥ pravayaso dhyānāt* serves also a chronogram to give the date of completion of the work. This chronogram works out to A.D. 1592, when Acyuta Piṣāraṭi, pupil of Jyeṣṭhadeva, composed the work.[11]

Whish, in his article referred to above, records a tradition that the author of the *Yuktibhāṣā* wrote also a work called *Dṛkkaraṇa*.[12] The *Dṛkkaraṇa* in question, an astronomical manual in Malayalam verse, is available in manuscript form (no. C. 7-C of the Kerala Univ. Mss. Library) but does not give anywhere the name of its author. However, it gives its date of composition in its final verse through the *Kali* chronogram *Kolambe barhisūnau* (*Kali* days 7, 83, 391) which would be A.D. 1608. In view of the tradition recorded by Whish and this date being not far from 1592 mentioned by Acyuta Piṣāraṭi, we might take the *Dṛkkaraṇa* to be a work of Jyeṣṭhadeva and that he lived up to about 1610.

In view of the facts that Dāmodara (c. 1400-1500) was a teacher both of Nīlakaṇṭha Somayāji and Jyeṣṭhadeva, and that Jyeṣṭhadeva wrote his *Yuktibhāṣā* in the wake of Nīlakaṇṭha's *Tantrasaṅgraha*, he must be a younger contemporary of Nīlakaṇṭha. He is remembered in 1592 by his pupil Acyuta Piṣāraṭi as *pravayas* ('very old'). His *Dṛkkaraṇa*

is dated in 1608. Jyeṣṭhadeva should, therefore, have been long-lived, his date being c. 1500-1610. His family house Paraṅṅoṭṭu (Skt. Parakroḍa) still exists in the vicinity of Ālattūr and Tṛkkaṇṭiyūr where well known astronomers like Parameśvara, Nīlakaṇṭha and Acyuta Piṣāraṭi flourished about those times.

Scope and extent of *Gaṇitayuktibhāṣā*

The entire text of *Gaṇitayuktibhāṣā* occurs as one continuum, without any internal or closing colophons to mark off the subjects treated in the work. However, towards the middle of the work, where the treatment of mathematics ends and that of astronomy commences, occurs a general benedictory statement which reads: *Śrīr astu, hariḥ śrī-gaṇapataye namaḥ, avighnamastu*. This would naturally mean that the author had conceived his work as consisting of two parts, devoted respectively to mathematics and astronomy. Since the work deals with several main subjects and a number of topics under each, the needed subject and topic divisions shall have to be made editorially with suitable indication. Demarkating the work thus, the main subjects treated in Part I: Mathematics are : *Parikarma* (Logistics), *Daśapraśna* (Ten problems involving logistics), *Bhinnagaṇita* (Fractions), *Trairāśika* (Rule of three), *Kuṭṭākāra* (pulverization), *Paridhi-vyāsa* (Relation between circumference and diameter) and *Jyānayana* (Derivation of Rsines). The subjects treated in Part II. Astronomy are: *Grahagati* (Planetary motion), *Bhagola* (Sphere of the zodiac), *Madhyagraha* (Mean Planets), *Sūryasphuṭa* (True Sun), *Grahasphuṭa* (True Planets), *Bhū-vāyu-bha-gola* (Spheres of the Earth, Atmosphere and Asterisms), *Ayanacalana* (Precession of the Equinoxes), *Pañcadaśapraśna* (Fifteen problems relating to spherical triangles), *Digjñāna* (Orientation), *Chāyāgaṇita* (Shadow computations), *Lagna* (Rising point of the Ecliptic), *Nati-lambana* (Parallaxes of Latitude and Longitude), *Grahaṇa* (Eclipse), *Vyatīpāta*, and *Śṛṅgonnati* (Elevation of the Moon's horns).

Kriyākramakarī, *Yuktidīpikā* and *Gaṇitayuktibhāṣā*

There are two extensive commentaries, both by Śaṅkara Vāriyar of Tṛkkuṭaveli family (A.D. 1500-1560), being *Kriyākramakarī* and

Yuktidīpikā, the former on the *Līlāvatī* of Bhāskara II, [13] and the latter on the *Tantrasaṅgraha* of Nīlakaṇṭha Somayāji.[14] Interestingly, there is a close affinity between the *Yuktibhāṣā* and the above-said two commentaries. Even more, there is some sequence of arguments and verbal correspondences amongst them in the treatment of identical topics. From this similitude it has been suggested that the *Yuktibhāṣā* is just a rendering into Malayalam of certain passage from that Sanskrit. It is further suggested that for this reason, there is not much that is original in the *Yuktibhāṣā*[15]. But the fact is just the other way round, namely that the Sanskrit versions are adaptations and paraphrases of the relevant portions from the *Yuktibhāṣā.* This is confirmed by Śaṅkara, the author of both the commentaries, when he states specifically in the colophonic verses of his commentary *Yuktidīpikā* on the *Tantrasaṅgraha,* that what he had done in the commentary was only 'the setting out of the material elucidated in the work of the Brāhmaṇa of Parakroḍa (viz. Jyeṣṭhadeva) (author of the *Yuktibhāṣā)* ' *Cf.*, for instance one such colophonic verse:[16]

इत्येष परक्रोडावास-द्विजवर-समीरितो योऽर्थः।
स तु तन्त्रसंग्रहस्य प्रथमेऽध्याये मया कथितः।।

Yuktibhāṣā* and *Gaṇitayuktibhāṣā

There is a work entitled *Gaṇita-yuktibhāṣā* (Ms. No. R. 4382 of the Govt. Or. Mss. Library, Madras) in Sanskrit and it has been suggested that it might be the source of the Malayalam *Yuktibhāṣā.* However, a detailed comparison of the two shows that the *Gaṇita-yuktibhāṣā* is but a rough and ready translation into Sanskrit of the Malayalam original by one who lacked not only the ability of writing idiomatic Sanskrit but also an adequate knowledge of the subject. Moreover, at places there occur haplographical omissions in the Sanskrit version passages available in the Malayalam work, which fact too confirms that the Sanskrit version is the derived form.

Presentation of The Rationale

The mathematical and astronomical rationale presented in the *Yuktibhāṣā* relate to several aspects, to wit, concepts, theories,

constants, computations, demonstration by diagrammatic representation and the like. The procedure of depiction is logical, going step by step, first presenting the fundamentals and gradually building up the argument. It is, if one might say so, 'intimate' in that, it inculcates the rationales and elucidates the steps even as a teacher does to a student. The work aims at understanding and conviction by the reader. A passage might be cited to illustrate the point. The selected passage relates to the concept of the motion of the planets:

Grahaṅṅaḷuṭe Gatiprakāram:

Iviṭe grahaṅṅaḷellām oru vṛttamārgeṇa gamikkum, divasattil vṛttatinte itra aṃśam gamikkum ennu niyatam tānum, aviṭe divasattil itra yojana gamikkum ennuḷḷa yojanāgati ellā grahattinum samam, aviṭe ceriya vṛttattiṅkal gamikkunnavattinnu kuraññoru kālam koṇṭu vaṭṭam kūṭum, valiya vṛttattiṅkal gamikkunnavattinnu perikekkālam kūṭiyē vaṭṭam tikayū, enniṭṭu candrannu irupattēzhu divasam koṇṭu pantraṇṭu rāśiyiṅkalum gamiccu kūṭum, muppattiraṇṭāṇṭu kūṭiyē śani naṭannu kūṭū, vṛtattinte valippattinnu takkavaṇṇam kālattinte perukkam, atātu graham tante vṛttattiṅkal oru vaṭṭam gamiccu kūṭunnatinu bhagaṇam ennu pēr, Caturyyugattiṅkal etra āvṛtti gamikkum tante tante vṛttattiṅkal atu tante tante yugabhagaṇam ākunnatu.

Iviṭe candrane oru nāḷ oru nakṣatrattōṭu kūṭe kaṇṭāḷ pittennāḷ atinte kizhakke nakṣatrattōṭu kūṭe kāṇām, Itinekkōṇṭu candranu gatiyuṇṭennum kizhakkōṭṭu gatiyennum kalpikkām, kizhakkōṭṭu rāśikramam ennum kalpikkām I

Ivṛttaṅṅaḷkku ellāttinum kūṭi oru pradeśatte ādiyennu kalpikkumāruṇṭu, Aviṭattinnu meṣarāśiyuṭe ādiyennu pēr, ī goḷattiṅkal kalpikkunna vṛttaṅṅaḷe ellāttēyum irupattōrāyirattarunūru khaṇḍamāyi vibhajikkumāruṇṭu, Itil ōrō khaṇḍam iliyākunnatu I iva valiya vṛttattiṅkal valutu, ceriya vṛttattiṅkal cerutu, saṅkhyā ellāttinkalum okkum, atatu graham tante tante vṛttattiṅkal itra īli gamikkum ōrō divasam ennu niyatam I graham gamikkunna vṛttattinte kendrattiṅkal irunnu nōkkum dṛṣṭāvu eṅkil nityavum gati okkam ī grahattinnu ennu tōnnum, bhūmadhyattiṅkēnnu oṭṭu cellū grahavṛttakendram I bhūmīṅkalu

draṣṭāvu, īdraṣṭāviṅkal kendram āyiṭṭu oru vṛttam kalpippū grahattoṭu sparśikkumātu । āvṛttattiṅkal etra cenniṭṭirikkum graham atra cennū meṣādiyiṅkal ninnu graham ennu tōnnum ī draṣṭāvinu, Itariyum prakāram sphuṭakriyayākunnatu'।

Planetary Motion

Now, all planets move along circular (orbits). The number of minutes what each planet takes to move in its orbit in the course of a day is fixed.

There, the number of *yojana*-s moved per day is the same for all planets. For planets, which move along smaller orbits the circle would be completed in a shorter time. For those, which move along bigger orbits the circle would be completed only in a longer period. For instance, the Moon would have completely moved through the twelve signs in 27 days, while Saturn will complete it only in 30 years. The length of time taken is proportional to the size of the orbit. The completion of one motion of a planet in its orbit is called a *bhagaṇa* (of that planet). The number of times that a planet moves in its orbit during a *catur-yuga* is called its *yuga-bhagaṇa* (revolutions per aeon).

Now, if the Moon is seen with an asterism on a particular day, it will be seen the next day with the asterism to the east of (the first one). From this it might be understood that the Moon has eastward motion. The sequence of the signs can also be understood as eastward. For all these orbits, a particular point is taken as the commencing point. This point is termed as the *First Point of* Aries. All the circles in a sphere are divided into 21,600 equal parts. Each part is a minute. They are larger (in length) in bigger circles and smaller in smaller circles, though the number of parts is the same in all. The number of minutes that a planet will move along its orbit during the course of a day is fixed. *If one perceives the said motion placing himself at the centre of* the orbit of a planet, the motion of the planet would appear equal every day. The centre of the planetary orbit is the centre of the earth. The perceiver is, however, situated on the Earth's surface. Conceive a circle with the perceiver as centre and touching the planet. The perceiver

would see the planet as much advanced from the *First Point of* Aries as the planet has advanced in the said circle. The method by which the perceiver ascertains this (advanced) point is called 'Computation of the True planet'.

Analytic Contents of the *Gaṇitayuktibhāṣā*

As mentioned earlier, Pt. I. of the *Yuktibhāṣā,* dealing with Mathematics, can be divided into seven chapters.

Ch. I. on Logistics (*Parikarma*) deals with the Nature of numbers (pp. 1-2),[17] Multiplication as explained from several standpoints including the use of diagrams (pp. 2-9), Multiplication by easy methods (pp. 9-13), Divison (p. 15), Squaring in its several methods (pp. 15-29), and Roots of sums of squares and difference of squares (pp. 29-31).

Ch. II. *Daśapraśnottara* (Ten algebraic problems and their solutions) relates to the finding of two numbers when two from among the five, viz., their sum, difference, product, sum of squares and difference of squares, are given. (pp. 32-35).

Ch. III. Deals with Fractions (pp. 36-44). Highly analytical in presentation, the topics dealt with are: Nature of fractions, their addition, subtraction, multiplication and divison.

Ch. IV. is entirely devoted to the Rule of three, where both its general and inverse rules are set out (pp. 45-49).

In **Ch. V** (pp. 50-71), the importance of the Rule of three in mathematical and astronomical computations is indicated with the computing of the current *Kali* day.

. The Mean Planets are divided therefrom. *Apavartana* (Reduction) and *Kuṭṭākā* (Pulverisation) are introduced here and their purpose specified. An elaborate rationalization of the principles involved in it and the practices followed in both Reduction and Pulverisation is made and explained with examples. It is also indicated how the process helps in arriving at the *Bhājya*'s (Divisers) and *Bhājaka*'s (Multiplicands) in Pulverisation by means of the *Vallī* (Series of divisons), towards computing the planets more and more accurately.

In **Ch. VI** (pp. 72-142), the *Yuktibhāṣā* gives several formulae for determining the circumference of a circle of a given diameter. Some of the methods involve the properties of right angled triangles, towards which the properties of right angled triangles are demonstrated graphically. For the method which involve different summations of series, the derivation of those series is also demonstrated. Among the latter are the summations of consecutive numbers, the summation of squares, the summation of cubes and higher powers, and the summation of summations. In the case of certain formulae, *Yuktibhāṣā* enunciates further rules towards making the derived results more and more accurate (pp. 120ff.). Attention of scholars might be drawn here to a series of papers where in Prof. C.T. Rajagopal, Director, Ramanujam Institute of Mathematics, University of Madras, and his associates have worked out, in terms of modern mathematics, the above-said series and the different formulae enunciated in the *Yukibhāṣā*. They have also shown that these are independent of the discoveries made more than a century later by the Western scientists, James Gregory (1671), G. W. Leibniz (1673) and Issac Newton (1670). [17a]

Ch. VII (pp. 143-290) forms a long disquision of rationales relating to Rsines, their modifications and allied subjects. The chapter commences with an elaborate exposition of the geometrical derivation of the 24 Rsines for 3°45′ each (pp. 143-50), and explanations of allied terms like Rcosine, Rversed sine, arc, *bhujākhaṇḍa, koṭikhaṇḍa, jīvākhaṇḍa* and *khaṇḍajyā*, and their mutual relationship (pp. 150-60). Some of the other topics elucidated herein are : Accurate determination of the Rsines (pp. 160-65), Computation of the Rsines of any given arc (pp. 165-73), Computation of the arc of any given Rsine (pp. 173-75), Summation of Rsine differences and Reversed sine differences (pp. 176-98), Accurate determination of the circumference of a circle making use of the said summations (pp. 198-206), Addition of Rsines of two angles (pp. 206-24, 237-44), Cyclic quadrilaterals and their properties (pp. 224-37, 247-64), Square of the area of a circle (pp. 264-72), Derivation of Rversed sines (pp. 272-75), Derivation of Rsine shadow (pp. 275-78), Surface area of a sphere (pp. 278-82), and Volume of a sphere (pp. 282-90). The author of the

Yuktibhāṣā elucidates the rationales of the several items either geometrically or algebraically or using both means as the occasion demands.

Part II of *Yuktibhāṣā* contains many interesting formulae which are scarcely found in other works. For the sake of convenience, this Part is amenable to be divided into ten chapters, VIII to XVII, in consideration of the subject dealt with in them.

Ch. VIII deals with the Planetary Theory. At the outset, the concepts of the Sun, Moon and other planets, their linear velocities and angular motions are described. As in other Hindu astronomical treatises, the assumption is made that the linear velocity of all planets is the same but the angular motion varies depending on the dimension of their circular orbits. The Epicycle Theory for the sun and the moon and for the other planets and the interaction of the *manda* and *śīghra* epicycles are explained. There is a new concept in the treatment of the epicycles as compared to the *Āryabhaṭīya* and other works.

In a nutshell the planetary theory broadly is like this. The earth is the center and the sun and the moon go round the earth. As for other planets, with earth as center the *śīghra* goes round the earth with the mean motion of the sun. The mean planet moves on a circle with *śīghra* as center. The true planet is on the *mandocca* circle with mean planet as its centre. Alternatively, the last two circles can be interchanged. This theory is advocated by Nīlakaṇṭha in his commentary on *Āryabhaṭīya* and practically all later Kerala authors have followed suit. In fact Nīlakaṇṭha tries to say that it was the view of Āryabhaṭa also. If *śīghra* is identified with the sun itself then this agrees broadly with the modern theory with the positions of earth and sun reversed. In fact the western astronomer Tycho Brahe (1546-1601) appears to have adopted a similar theory.

The rationale for adopting three or four stages of operations to find the geocentric longitude of a planet is also explained. This particular aspect has been baffling the scholars as the rationale for this is not to be found in any work. It is generally believed that the Hindu astronomers

were not aware that the true geocentric longitude is to be obtained in two steps by first applying the *manda* correction, and using the corrected planet the *śīghra* equation is to obtained and applied to the once corrected planet; therefore they adopted different methods involving three or four stages in different ways.[18] However later Kerala works like *Sphuṭanirṇaya* have clearly explained the procedure in two stages correctly. This is not surprising if the longitude is arrived at on the basis of the planetary theory described above. Nīlakaṇṭha also in his commentary on Āryabhaṭīya has given a similar method. Then how and why these three or four stages method got in. Some explanation has been given in some papers.[19] But in the *Yuktibhāṣā* the rationale has been expounded beautifully. In short it is like this. In arriving at the *śīghra* correction the Mean *mandakarṇa* is taken instead of True *mandakarṇa*. This is because the tables of *śīghra-jyās* can be constructed only on the basis of mean *mandakarṇa*. Hence a correction becomes necessary for the *śighra-phala*. To achieve this a correction is effected in the true *manda* planet in such a way that this connection together with its effect or the tabular *śīghra-phala* will compensate for the error in *śīghra-phala* due to the difference in *mandakarṇa*. The longer commentary on *Tantrasaṅgraha* also gives this rationale as also the planetary theory. There are many small tracts[20] in Kerala wherein various alternate methods are advocated to give effect to this correction. It is a moot point whether Āryabhaṭa and other astronomers were aware of this rationale or they just hit at these methods by trial and error.

The treatment of latitude with regard to the planets in the *GYB* is satisfactory. The theory is that the *śīghra* circle is always on the ecliptic plane and only the plane of the planet's path gets deflected. This accords with facts and therefore the resulting helio and geocentric latitudes also represent the correct position as also the distance between the earth and the planet making allowance for the latitude.

Ch. IX deals with Celestial Sphere. This chapter deals with the celestial sphere and the related great circles such as meridian, horizon, equator, ecliptic and their secondaries, and the small circles

such as day parallels etc. The poles of great circles and their relation with mutually perpendicular great circles, the equinoctial and solstitial points are explained. First the celestial sphere for an observer on the terrestrial equator is described and then changes are explained as the observer moves to a northern latitude. Then the effects of *Ayana-calana* or the backward motion of the *First Point of* Aries on the equator, ecliptic etc., are considered. Lastly the procedure for construction of an armillary sphere is described.

Ch. X is on Declination, Right Ascension and related problems. In the first place the declination (*krānti*) of the sun (an object of the ecliptic) is considered. The formula for this sin (declination) = sin (longitude) x sin (obliquity), is got by using the properties of similar triangles and by proportion. In addition, two more concepts, which are not found in other works are introduced. These are: Draw a secondary to the equator through the *First Point of* aries and a great circle through the solstitial points and the sun. The arcs between their point of intersection and the sun and the *First Point of* aries are called *Krāntikoṭi* and *Nata,* respectively. (*Krāntikoṭi* is not cos *krānti* which is known as *dyujyā*). We may call them as 'inverse declination' and 'inverse R. A.'. These concepts are used to determine various other formulae which are described in the next chapter. Then the method of arriving at the R. A. or *Kālajyā* is described.

But the most important derivations in this chapter are the exact formulae for declination and R. A. of a star which is not on the ecliptic and therefore has a latitude, not necessarily of a small magnitude. This problem has not been satisfactorily solved by Indian astronomers till then and only approximate solutions have been given which are valid only if the latitude is small.[21] The formulae derived here accord with the modern formulae.

Ch. XI has tackled 15 problems. Taking the sun and the *krānti* triangle and the *krāntikoṭi* triangle there are six elements viz., longitude, R. A., declination, obliquity of the ecliptic, *nata* and *krāntikoṭi.* The problem is, given two of these six the other four are to be found out. There will be in all 15 cases which will arise. All these cases are

examined and the methods for finding the other 4 elements are discussed exhaustively from fundamentals. This is a very interesting and instructived exercise to understand how the contemporary astronomer's mind worked in solving problems on spherical trigonometry.

Ch. XII deals with Direction and Shadow. This chapter starts with the method for finding accurately the east-west and north-south lines or directions. The method adopted is the familiar one, marking off the points where the shadow of a gnomon touches the circumference of a circle with centre at the foot of the gnomon, forenoon and afternoon, and joining them to get the east-west line. Since there will be a change in the declination of the sun between the forenoon and afternoon this line will not accurately depict the east-west line and a correction is provided to rectify the error. The *Kujyā* and *Carajyā* are defined and the formulae derived. The method for arriving at the shadow for given time is next considered and the standard method is adopted. But in this two corrections are made. The sun is not a point but a sphere and the umbra is to be taken as the shadow and a correction is needed for this. Secondly the correction due to the parallax of the sun is also explained. The .converse problem of finding time from shadow is trackled by the standard method after giving effect to the above two corrections. Then the problems connected with noon shadow, *samaśaṅku,* corner shadow etc., are dealt with in the usual manner.

Ch. XIII is again an interesting section concerned with shadow problems. We have five elements of the spherical triangle joining the sun, zenith and north pole. The five elements are the three sides and two angles of the triangle. That is, zenith distance, co-declination, co-latitude, which are the three sides and, the azimuth and the hour angle the two angles. (Actually the text would use either these elements or their complements). Out of these five, if any three are known, the problem is to find the other two. There will be ten cases to be solved. All these cases are taken up and the solutions are derived methodically on the basis of the properties of spherical triangles.

This subject is dealt with in *Tantrasaṅgraha* also as it should be and based on this R. C. Gupta has presented a detailed paper.[22]

He has however remarked that the rationales of the rules are not given in the work (*Tantrasaṅgraha*) and his paper verifies the rules by the modern formulae. Well ! the rationales are fully documented here in *Yuktibhāṣā.* In fact the rationales are also given in the longer commentary on *Tantrasaṅgraha,* that is, *Yuktidīpikā.*

Ch. XIV is on *Lagna* and *Kālalagna*. The equator cuts the horizon of any place at two fixed points, east and west. The ecliptic also cuts the horizon at two points but since the position of the ecliptic varies every moment these points also vary moment to moment, oscillating on either side of the east and west points. These two points at east and west are called *Udayalagna* and *Astalagna* or the rising and setting points of the ecliptic. The distance from the First Point of the aries to the east point and *Udayalagna* are called the *Kālagna* and *Lagna*, respectively. This chapter deals with the method of calculating these two longitudes. Arriving at the *lagna* is a standard problem in all texts. The procedure followed generally is to find the rising times of the twelve signs for the local place and from the longitude of the sun obtain by interpolation the longitude of the rising point or *lagna* for the desired time. This is bound to be approximate. However, in *Yuktibhāṣā* a direct method is adopted. First the zenith distance of nonagesimal (*dṛkkṣepa*) is obtained and from that the *lagna* is arrived at. This method perhaps is again one of the Kerala methods.

Ch. XV deals with Eclipses and Parallax Corrections. In the treatment of the circumstances of an eclipse there is not much to comment. However we deal with two matters, one the second correction for the moon and the other the effect of parallax in longitude and latitude. The second correction for the moon which takes the place of the modern Evection plus the deficit in the equation of centre of the moon was known in India at least from the 10^{th} century. There is a detailed paper by K. S. Shukla on this subject[23] wherein he has dealt with this subject as contained in *Tantrasaṅgraha* also. As can be expected *Yuktibhāṣā* follows *Tantrasaṅgraha,* more or less, and in addition gives the basis for this correction. This basis or theory is the same as explained in Shukla's paper. However a refinement has been

made in this work and that is when the moon has a latitude its distance from earth should be calculated taking the latitude also into account.

Now coming to parallax the idea is to calculate effect of parallax in the longitude and the latitude known as *lambana* and *nati* respectively. The usual formula for these as is in vogue in Kerala texts are derived on the basis that the object is on ecliptic, that is, there is no latitude. While other texts deal with this problem differently giving in some cases only approximate results, the method followed there is exact. Further other texts do not take into account the latitude on the plea that during an eclipse the latitude of the moon is negligible. But here necessary formulae are derived to take into account the latitude also.

Then to determine the angle if the sun's or the moon's disc at which the eclipse starts or ends and to graphically depict an eclipse the valanas or deflections are required to be calculated. Generally the texts deal with two deflections *ayanavalana* and *akṣavalana* being the deflections due to obliquity of the ecliptic and the latitude of the place respectively. In *GYB* in addition, a deflection due to latitude of the moon is also derived. This deflection is generally found in other Kerala works also.

Ch. XVI is on *Vyatīpāta*. *Vyatīpāta* occurs when the sun and the moon have equal declination and they are in the same *ayanabhāga* but in different quadrants or in different *ayanas* but in the same type of quadrant, odd or even. This is considered very inauspicious, particularly in Kerala, and the days on which *vyatīpāta* falls are discarded for the performance of good *karmas.* All Kerala works on astronomy devote a chapter for determining *vyatīpāta.* Not only this, there are full fledged works which deal with exclusively *vyatīpāta* and as in the case of eclipses the beginning, middle and ending of *vyatīpāta* are defined and the methods to arrive at these moments are also explained. From the definition it will be seen that the declinations of the sun and the moon are required to be calculated for this purpose. The declination of the sun presents no difficulty. In the case of the moon allowance has to be made for the latitude. The method of arriving at the exact declination of the moon has already been explained in Chapter IX.

In this chapter an alternate method is given with its rationale. The method adopted is like this. The angle between the moon's path and equator is not constant but varies between 19.5 to 28.5 degs. depending upon the position of its node. The exact figure for the moment is first obtained. Then the distance between the point of intersection of the moon's path and the equator, and the moon is got by marking a correction to the node's longitude.

This correction is called *Vikṣepa-calana.* The method of arriving at these two elements, with rationale, is explained. With these two elements the declination of the moon is obtained in the same way as for the sun. This is a very interesting procedure and appears to be peculiar to Kerala.

In **Ch. XVII**, *Dṛkkarma* or Reduction to observation is explained with rationale as also *Candraśṛṅgonnati* relating to the phases of the moon.

As is his wont, throughout the work, Jyeṣṭhadeva, the author of *Gaṇitayuktibhāṣā,* elucidates the rationales of the several items, either geometrically or algebraically or using both means as the occasion demands. Towards a full evaluation of the work, it is necessary to deal in detail, in terms of modern mathematics, with the numerous rationales and theories, some of them new, adumbrated in the work. It may be added that *Yuktibhāṣā* has been edited by the present writer with translation and elucidation of the entire text which, is in the Malayalam language, and also *Gaṇita-yuktibhāṣā*, the Sanskrit rendering of the Malayalam original.

Model Demonstration from *Gaṇitayuktibhāṣā*

Here we demonstrate some of the derivations as explained in the *Gaṇitayuktibhāṣā.* We generally follow the logic as found therein but with some modification here and there for the sake of convenience and ease of understanding.

The *Yuktibhāṣā* uses the radian measure as the radius for the sines of all angles. As a matter of fact, the angles as such are not at all used, and all angles are measured in arcs only. Thus, the full circle of 360 degree or 21600 minutes (minutes are the usual unit of measure with sub-divisions of seconds etc., wherever needed) is taken as the circumference and, on this basis, the radius is measured as 3438 minutes which is sin 90^0, and, accordingly, the sines of all angles are measured and used for various calculations. However, in out modern conventions as this will not affect the arguments used in the derivations or rationales.

Only the sine function is used though the cosine function is also well known. Whenever the cosine function is to be used the sine of the co-angle (90^0 minus the angle) is used or some times $\sqrt{1 - \sin^2}$ is used. Sometimes the angle and its sine are used as synonyms and from the context one has to decide whether it refers to the angle or sine.

No general formulae have been derived for the solution of spherical triangles. But the properties of small and great circles and the relations between mutually perpendicular great circles and their poles, and the properties of similar triangles are used with imagination. The presentations are quite long and detailed and verbose. Anybody who reads this will get an impression that, while writing this, the author had before him a model of the celestial sphere and expects and readers also to have one before them. It may be mentioned that the procedure for constructing such an armillary sphere has also been explained in the text.

We shall discuss the solutions with their rationale to the following four problems.

i. Declination and R. A. of the Sun.

ii. One of the fifteen problems.

iii. Declination and R. A. of a star with a latitude.

iv. One of the ten problems.

I. Declination and R. A. of the Sun

The Hindu method of solving this problem is well known, but still for the sake of completeness we start with this.

See Fig.1

In this figure:

P - Pole of Equator RLQ.
R - *First Point of* Aries.
S - Sun of Ecliptic RSC

Draw CU and SN $\perp$ to the plane of Equator ROQ.
Draw NT and LM $\perp$ OR on the plane of Equator.

It will be seen that

CQ or $\angle$ COQ Obliquity of the Ecliptic (w) and CU its sine.
RS or $\angle$ ROS Longitude of the Sun (1) and ST its sine.
SL or $\angle$ SOL Declination of the Sun (d) and SN its sine.
RL or $\angle$ ROL R. A. of the Sun (a) and ML its sine.

Since the two traingles COU and STN are similar we have, SN/ST = CU/CO or SN = ST x CU as CO = 1 being the Radius.

So we get the declination formula

$$\sin d = \sin 1 \times \sin w$$

The radius of the diurnal circle of the Sun is ON and TN is the sine R. A. on this circle.

$$TN = \cos d \times \sin a \quad \text{or} \quad \sin a = TN/\cos d$$

Also from the two similar triangles considered above we have

$$TN/TS = OU/OC \text{ or } TN = TS \times OU \text{ or } TN = \sin 1 \times \cos w$$

Thus we have,

$$\sin a = \sin 1 \times \cos w/\cos d$$

which is the formula for R. A.

In the subsequent demonstrations we shall take into account the results of these derivations without again going into the details. This will also apply to spherical triangles in similar situations of the type SRL considered here.

We had referred to two more elements in the main paper in this connection. They are shown in Fig. I as SV and VR.

SV *Krāntikoṭi* or inverse declination (d_1)

VR *Nata* or inverse R. A. (a_1).

These can be calculated from triangle RSV in a similar way keeping in mind that ∠ SRV is 90^0 - w. thus

$$d_1 = \sin 1 \times \cos w$$

and

$$a_1 = \sin 1 \times \sin w / \cos d_1$$

It will be seen that

$$\sin^2 d + \sin^2 d_1 = \sin^2 1$$

II. One of the fifteen problems

As stated in the main paper these 15 problems are, given two out of the six elements viz., w,d,d_1,1,a,a_1 to find the other four. We shall take the case where d and a are given.

In Fig. 1 considering the triangles *PSC* and PLQ we have

$$\sin SC = \sin PS \times \sin LQ$$

or

$$\sin (90^0\text{-}1) = \sin (90^0\text{-}d) \times \sin (90^0\text{-}a)$$

(This is the same as the present cosine formula)

From this 1 can be calculated. Then by the declination formula, w can be calculated and the rest as in I above.

Alternatively, considering triangles PVS and PRL we have

$$\sin SV = \sin PS \times \sin RL$$

or

$$\sin d_1 = \sin (90^0 - d) \times \sin a$$

So d_1 is known. Obtain 1 from the relation

$\sin^2 1' = \sin^2 d + \sin^2 d_1$. others as before.

III. Declination and R. A. of a star with a Latitude

See Fig. 2

There

P, P_1	Poles of the Equator.
K, K_1	Poles of the Ecliptic.
RQ and RC	Equator and Ecliptic.
R	*First Point of* Aries.
S	A star away from ecliptic.
*PS*L and KSAX	Secondaries to Equator and Ecliptic through S.

Take a point B on the ecliptic 90^0 behind A. Draw PYB and KNB secondaries through B to equator and ecliptic and AM to the Equator. Draw AD and SW secondaries to PRP_1

Given RA the longitude (1) and SA the latitude (v) find SL, the declination (d) and RL the R.A. (a).

AM is the declination of the point A on the Ecliptic, say d'

And so $\sin d' = \sin 1 \times \sin w$

$BK = BA = 90^0$. So B is the pole of AK. Therefore BT and XT are mutually perpendicular as also XY and YT. Hence X is the pole of BP. Now consider the trainagles XSL and XTY. XT and XY are equal to 90^0. SL is perpendicular to LQ.

Therefore

sin SL = sin SX x sin TY or sin d = sin (v + AX) x sin TY or
sin d = sin v x cos AX x sin TY + cos v x sin AX x sin TY
From XAM we get sin AX x sin TY = sin AM. But AM = d'

So the second term for sin d is cos v x sin d' where both v and d' are known. As for the first term

$\cos^2 AX \times \sin^2 TY = \sin^2 TY - \sin^2 AX \times \sin^2 TY$
L.H.S. $= (1 - \sin^2 BY) - \sin^2 AM$

$= 1 - \sin^2 w \times \cos^2 1 - \sin^2 w \times \sin^2 1$
$= 1 - \sin^2 w = \cos^2 w$

Hence cos AX x sin TY = cos w. Hence the expression for d is

sin d = sin v x cos w + cos v x sin d'

which is the final form given in the book.

Putting sin d' = sin 1 x sin w we get the modern form:

Sin d = sin v x cos w + cos v x sin 1 x sin w

For the R. A. a similar method is adopted. It can be seen that

sin WS = sin ES x sin UV = sin (AE - v) x sin UV

Then proceeding on the same lines as for declination we get

sin WS = sin 1 x cos w x cos v - sin v x sin w

But from PWS and PRL we get sin WS = sin *PS* x sin RL

and since *PS* = 90^0 - d and RL = a, we get the expression for a,

Sin a = (sin 1 x cos w x cos v - sin v x sin w)/cos d

This expression can be obtained from the modern formulae

cos w x sin 1 = sin w x tan v + cos 1 x tan a, and
cos a/cos v = cos 1/cos d.

IV. One of the ten problems

See Fig. 3.

Here SENW is the horizon, S, E, N and W being the south, east, north and west points. P is the pole, Z zenith, and M the object, and EQW equator.

Draw ZMM_1 vertical through M. Take M_3 on the horizon 90^0 from M_1 and LPM_3 secondary to the equator through M_3. Draw MV, a small circle parallels to equator and MX perpendicular to ZQ. VQ is therefore equal to the declination of M.

In the triangle ZMP, given : PM (90^0 - d)

Latitude of the place : PN φ

Aḷimuth (A) or A - 90^0 : M_3N_2 B

To get Altitude M_1M = a, and Hour angle $\angle$ MPZ = H,

We shall get ZM the zenith distance z, and hence a = 90^0 - z

Now z = ZM = ZU - MU. We shall get ZU and MU.

M_3 is the pole of M_1, MZ. Therefore $UM_3 = 90^0$ and, U being on the equator, UP = 90^0. Hence U is the pole of M_3PJL.

Therefore UJ = UL = 90^0. Now, from the triangles UJL and UZQ we get,

sin QZ = sin ZU x sin LJ, and so sin ZU = sin QZ / sin LJ

QZ = φ , LJ is to be got. Now, M_3J = PL = 90^0, so, LJ = PM_3.

From M_3ZN and TZP we have $\sin^2 PT + \sin^2 PN = \sin^2 PM_3$

But from M_3TP and M_3PN we get sin PT = sin ZP * sin M_3N

or sin PT = cos φ x sin B.

Hence the previous equation becomes $\cos^2 \varphi \times \sin^2 B + \sin^2 \varphi = \sin^2 PM_3$

or sin M_3P = " $\sin^2 \varphi + \sin^2 B$ x $\text{con}^2 \varphi$ = D, say,

The expression in R.H.S. is called the 'Divisor' in *Tantrasaṅgraha* and denoted by D in Gupta's paper.

Substituting this value we get

$\sin UZ = \sin \varphi / D$

Now, to get UM, consider ZQU $\sin UM/\sin UZ = \sin QV / \sin QZ$ or $\sin UM = (\sin \varphi / D) \times \sin d / \sin \varphi$

or $\sin UM = \sin d/D$

we get $ZM = ZU - MU = \sin^{-1} (\sin \varphi/D) - \sin^{-1} ((\sin d)/D)$

From this the altitude a is got by $a = 90^0 - ZM$.

To get the Hour Angle H,

From ZMX, $\sin MX = \sin z \times \cos B$ and
From PMX, $\sin MX = \sin H \times \cos d$ Hence we get
$\sin H = \sin z \times \cos B / \cos d$

Alternate expression for (a):

$\sin a = \cos z = \cos (\sin^{-1} ((\sin \varphi)/D) - (\sin^{-1} ((\sin d)/D))$

Expanding R.H.S. and simplifying we get

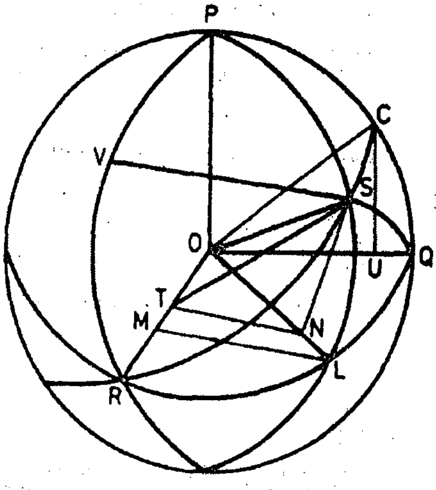
$[\sqrt{(D^2 - \sin^2 \varphi)} \times \sqrt{(D^2 - \sin^2 d)} - \sin \varphi \times \sin d]/D^2$

This is the expression given in *Tantrasaṅgraha* and quoted by Gupta in his paper.

As noted by Gupta, this expression can be got by the modern method by solving the following equation for sin a got by the modern cosine rule by transforming it into a quadratic equation.

$$\sin d = \sin \varphi \times \sin a + \cos \varphi \times \cos a \times \cos A.$$

It will be seen, the method of *Yuktibhāṣā* is entirely different and does not involve any quadratic equation.*



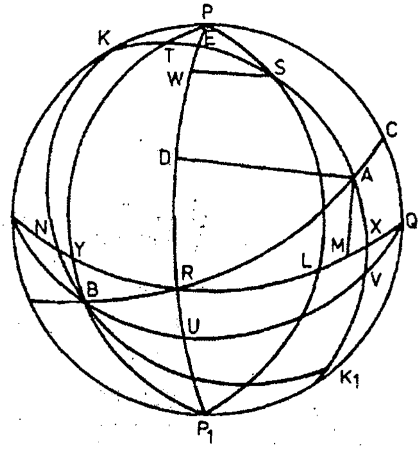


Fig.2

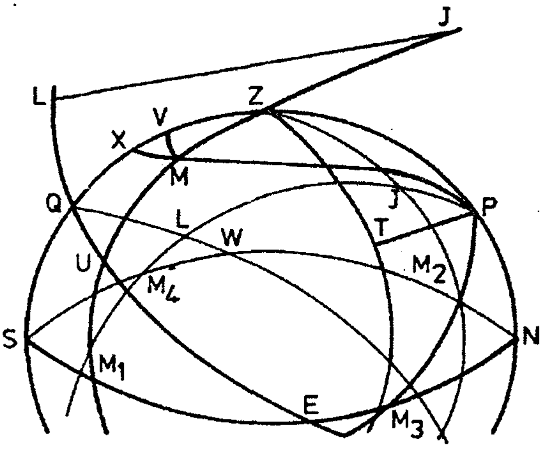


Fig. 3

NOTES AND REFERENCES:

1. From amongst texts of this type, might be mentioned: *Ganitayuktayaḥ* (Vishveshvaranand Inst., Hoshiarpur, 1979), *Rāśigolaphuṭānīti* (Hoshiarpur, 1977), *Grahaṇamaṇḍana* of Parameśvara (Hoshiarpur, 1965), *Grahaṇa-nyāya-dīpikā* of Parameśvara (Hoshiarpur, 1965), *Kriyākramakarī* of Śaṅkara, Com. on the *Līlāvatī* of Bhāskara II (Hoshiarpur, 1975), and *Yuktidīpikā* of Śaṅkara, Com. on the *Tantrasaṅgraha* (Hoshiarpur, 1977), Sputacandrāpti of Mādhava (Hoshiarpur, 1973), *Jyotirmīmāṃsā* of Nīlakaṇṭha (Hoshiarpur, 1977) all edited critically by K. V. Sarma. A large number of tracts, big and small, containing astronomical rationale, have also been identified by him.

2. *Tantrasaṅgraha* of Nīlakaṇṭha Somayāji, ed. with two commentaries, *Yuktidīpikā* and *Laghuvivṛti*, both by Śaṅkara, ed. by K. V. Sarma, Hoshiarpur, 1977.

3. C. M. Whish, 'On the Hindu quadrature of the circle and the infinite series of the proportion of the circumference to the diameter

exhibited in the four *Sastras,* the *Tantrasaṅgraham, Yucti Bhasha, Carana Padhati* (Sic) and *Sadratnamala*'. Transactions of the Royal Asiatic Society of Great Britain and Ireland, III. iii. (1835), 509-23.

4. *Cf.* the statement: 'The testimonies as to the author (of *Tantrasaṅgraha*) and the period in which he lived, are the following...the mention made of him...by his commentator, the author of the *Yucti-bhasha,* Cellalura Nambutiri', p. 522. However, it has to be noted, incidentally, that Whish has made wrong identifications, when he states here : (i) that the author of *Tantrasaṅgraha* is 'Talaculattura Nambutiri' (p. 522), for it is correctly Gārgya Kerala Nīlakaṇṭha Somayāji; (ii) that *GYB* is a commentary on the *Tantrasaṅgraha,* which it is not; and (iii) that the author of *GYB* is Cellalura (i. e. Keḷallur) Nambutiri (p. 522), for it is actually Paraṅṅoṭṭu Nampūtiri, as would be shown below.

5. See *Op. Cit.,* p. 523.

6. Several manuscripts of the work are preserved under the two titles in the Kerala University Mss. Library, Trivandrum, the Sanskrit College Library, Tripunithura, and in private possission.

7. There is a fine edition of Pt. I of the work, now out of print, by Rama Varma Maru Thampuran and A. R. Akhileswara Iyer, Mangalodayam Press., Trichur, 1948 and an extremely unsatisfactory and error-ridden edition of the whole work issued by the Govt. Oriental Mss. Library, Madras, 1954.

8. *Cf.*, S. N. Sen, *A Bibliography of Sanskrit Works on Astronomy and Mathematics,* INSA, New Delhi, 1966, p. 74; C. T. Rajagopal and M. S. Rangachari, 'On an untapped source of Medieval Keralese Mathematics', Archive for History of Exact Science, 18 (1978) 89-101; C. T. Rajagopal and M. S. Rangachari, 'On medieval Kerala Mathematics', ib. 35 (1986) 91-99.

9. *Op. Cit.*, Introduction, p. 5, where the A.D. date is wrongly given as 1639; Ulloor, *History of Kerala Literature*, Trivendrum, Vol. III, 1955, p. 439.

10. For an independent tradition that the author of the *Yukibhāṣā* belonged to the Paraṅṅoṭṭu family (Sanskritised as Parakroḍa), situated in the Ālattūr village in Malabar, see Nampūtirimār (Mal.), by Parayil Raman Namputir, Trichur, Kollam era 1093, (A.D. 1918), p. 55.

11. See Ms. C. 628-B, end of the Kerala Uni. Mss. Library.

12. Whish, *loc. Cit.*, p. 523.

13. Cr. Edn. with introduction by K. V. Sarma, Vishveshvaranand Institute, Hoshiarpur, 1975.

14. Cr. Edn. with detailed Introduction by K. V. Sarma, Vishveshvaranand Institute, Hoshiarpur, 1977. The identity of the authorship of the two commentaries has been dealt with in detail herein, Intro., pp. ii-vi.

15. See, P. Sridhara Menon, Introduction to Maru Thampuran's edn. of the work. p. 6.

16. *Loc. Cit.*, pp. 5-6.

17. The page numbers here ref. to *YB.* ed. by Rama Varma Maru Thampuran.

17 a. (i) K. Mukunda Marar and C. T. Rajagopal, 'On the Hindu quadrature of the circle', *J of Bombay Branch of Royal Asiatic Soc.*, NS 20 65-82 (1944).

(ii) C. T. Rajagopal and A. Venkataraman, 'The Sine and Cosine power series in Hindu mathematics', *J. Royal Asiatic Soc. of Bengal, Sc.*, 15 1-13 (1949).

(iii) C. T. Rajagopal and M. S. Rangachari, 'On an untapped source of medieval Keralese mathematics', *Archive for Hist. of Exact Sciences,* 18 (1978).

(iv) C. T. Rajagopal and M. S. Rangachari, 'On medieval Keralese mathematics', *Archive for Hist. of Exact Sciences,* 35, 91-99 (1986).

18. See, for instance, E. Burgess, *Translation of the Sūryasiddhānta*, p. 86, lines 3 ff.; P. C. Sengupta, *Khaṇḍakhādyaka*, p. 58, last para.
19. O. Neugebauer, 'The transmission of planetary theories in ancient and medieval astronomy', *Scripta Mathematica*, New York, 1956, App. '*Hindu Planetary theory*', p. 12ff.
20. See for instance, K. V. Sarma, *Rationales of Hindu Astronomy*, Pt. I, Hoshiarpur, 1979, Tracts 24, 25 and 26.
21. See P. C. Sengupta, *Khaṇḍakhādyaka*, pp. 189-91, Problem viii.
22. R. C. Gupta, 'Solution of a astronomical triangle as found in the *Tantrasaṅgraha* (1500)', *Indian Jl. of Hist. of Science*, 9, 86-99 (1974).
23. K. S. Shukla, 'The evection and the deficit of the equation of the centre of the Moon in Hindu astronomy', *Proceedings of the Banaras Mathematical Society*, NS, 7. ii (Dec. 1945) 9-28.

♣ Acc. to some sources Prof. Sarma had observed that *Gaṇitayukibhāṣā* has 17 chs. However while preparing the critical edition of the text in Sanskrit Prof. Sarma has reorganised the second part consisting of 10 chs into 8 chs. as follows :

VIII to VIII
IX & X to IX.
XI to X
XII, XIII & XIV to XI
XV to XII
XVI to XIII
XVII to XIV & XV, thus totalling into 15.

◆ The book has been published now in 2 pts.; pt. 1. Sanskrit version by IIAS, Simla, 2004; pt. 2 in two vols. cr. ed. by K.V. Sarma and with expalnetory notes by A. Ramasubramanian, M.D. Srinivas and M.S. Sriram, pub by Hindusthan Book Agency, 2008.

THE *DEVĀLAYACANDRIKĀ*

A HITHERTO UNKNOWN WORK OF NĀRĀYAṆA, AUTHOR OF THE *TANTRASAMUCCAYA**

Nārāyaṇa, a Nampūtiri Brahman of the Cennās family in Kerala, is well-known author of Tāntric works. A contemporary of the *Mīmāṃsaka* scholars, Ṛṣi and Parameśvara of Payyūr, and Uddaṇḍa Śāstri, author of the *Mallikāmāruta* and *Kokilasandeśa*, our author (born A.D. 1428).[1] flourished as one of the 'eighteen-and-a-half' poets in the court of the Zamorins of Calicut during the fifteenth century.[2] His *Tantrasamuccaya*,[3] an elaborate treatise in twelve *Paṭala*-s, is a standard work on temple architecture and worship, widely popular in Kerala. The only other work by Nārāyaṇa, hitherto known, is the *Manuṣyālayacandrikā* (called also *Manuṣyālayalakṣaṇa* and *Mānavavāstulakṣaṇa*) on the construction of human residences.[4] Manuscripts of the *Manuṣyālayacandrikā* do not indicate its authorship and the identification is made on the basis of internal evidence and the external testimony of an anonymous commentary on the work.[5] The text begins:

praṇamya viśvasthapatim pitāmaham
nisargasiddhākhilaśilpanaipuṇam ।
mayā vivicyāgamasāram īryate
samāsato mānavavāstulakṣaṇam ॥

The commentary explains:

ayam kaviḥ 'mayā' tantrasamuccaye devālayalakṣaṇam uktam, manuṣyālayalakṣaṇam kutrāpi noktam ca; tasmād idānīm tantrasamuccayāt katipayapadyāni yathāvakāśam uddhṛtya taiḥ saha catuścatvāriṃśadbhiḥ ślokaiḥ manuṣyālayalakṣaṇaṃ vakṣyāmi 'iti niścitya tatrādau prathamena ślokena iṣṭadevatānamaskāraṃ cikīrṣitapratijñāṃ cāha- praṇamya viśvasthapatiṃ pitāmaham' iti.[6]

Adyar Library Bulletin, vol. XXV, parts 1-4 (1961)

The commentator states here that the author has composed the *Manuṣyālayacandrikā*, extracting appropriate verses from his *Tantrasamuccaya* and adding forty-four fresh verses to suit the subject treated. In the work itself, the *Tantrasamuccaya* verses are incorporated as an integral portion and not as extraneous quotations. The identification of Nārāyaṇa's authorship is made on these considerations.

There is yet another work which has not so far attracted the attention of scholars: the *Devālayacandrikā* or *Devālayalakṣaṇa*, bearing the same characteristics as the *Manuṣyālayacandrikā*, manuscripts of which are yet to be unearthed. But in the Madras Govt. Oriental Manuscripts Library, there is a detailed Malayalam commentary on this work (No. Mal. D. 245) which contains also a few verses of the text.[7] This text commences with the same introductory verse as the *Manuṣyālayacandrikā,* except for the last line where the subject treated in the work is specified as 'the construction of temples' instead of 'the construction of human residences', as in the case of the former work:

praṇamya viśvasthapatiṃ pitāmahaṃ
nisargasiddhākhilaśilpanaipuṇam ।
mayā vivicyāgamasāram īryate
samāsya devāyatanādilakṣaṇam ॥

In this work too verses from the *Tantrasamuccaya* are taken and freely used as in the *Manuṣyālayacandrikā*; only they are far more numerous here. The arguments for regarding the *Manuṣyālayacandrikā* as a work of Nārāyaṇa apply, in equal measure, to accepting the *Devālayacandrikā* as another work of this author. The similarity in the names of the two works is a piece of additional evidence.

The subject dealt with in the *Devālayacandrikā* is the construction of temples and images of Gods for worship. After the introductory verse, instructions are given for the selection of a proper site for the temple (vv. 2-6). The selected spot is then measured and consecrated (7-9). Detailed instructions follow for the actual building (10 ff.). The outer walls, pillars, sanctum sanctorum, drain, doorways,

decorations on the walls, etc., roofing, spires, halls, etc. are dealt with one after the other. The manuscript ends abruptly with verse 171, the last subject treated being the *Śivaliṅga*.

The bulk of the verses in this text are, as indicated above, not available in the manuscript, but each verse can be identified by the introductory sentence prefixed to its commentary and the commentary itself. The verses common to the *Tantrasamuccaya* have been identified below to show the relationship between the two works and indicate the fresh verses in this work:

Dev. Candrikā	*Tantrasamuccaya*	
1		Introductory verse
2	I. 28	
3-6	I.39-42	
7-8	I.54-55	
9	I.60	
10-22		Fresh verses
23-42	II. 1-20	
43-48		Fresh verses; these six verses are however found in some Mss. of the *Tantra-samuccaya*; *cf. TSS*. 151, App. V, pp. 9-10.
49-60	II. 21-32	
61		Fresh verse
62-100	II. 33-70	
101		Fresh verse
102-55	II. 71-124	
156-57		Fresh verses
158-71	II. 127-40.	

NOTES AND REFERENCES:

1. Vide the chronogram *kalyabdeṣv atiyatsu nanda-nayaneṣv ambhodhisaṅkhyeṣu yaḥ sambhūtaḥ* in his *Tantrasamuccaya*, XII. 215.

2. On these scholars and Nārāyaṇa himself, see: Ulloor, *Hisory of Kerala Literature*, II, 22 ff.; E.V. Raman Namputiri, *Introd. to Tantrasamuccaya* with Malayalam commentary, pt. III, Trivandrum, 1945, pp.92-115; and K. Kunjunni Raja, *The Contribution of Kerala to Sanskrit Literature*, Madras, 1958, pp. 63 ff.

3. *TSS*. 67, 71, 151 and 169; and *University of Travancore Malayalam Series* 64, 66 and 68.

4. Several Mss. of this work are available. Also edited under title *Ṣaṭpañcāśikā*, A *Śilparatna* Manual by K. Madhava Krishna Sarma in *ALB*, vol. 6, pp. 41-51, and with an old Malayalam commentary under the title *Vāstulakṣaṇa* in *Madras Govt. Or. Series* 22.

5 *Cf.* V.A. Ramaswami Sastri, *TSS* 151, Preface, p. ii; Ulloor, op cit., II, 64-5; E.V. Raman Namputiri, *op. cit.*, introd., pp. 118-19.

6. Ms. No. CO. 311, *Descriptive Catalogue of Skt. Mss. in the Curator's Office*, Trivandrum, VI, pp. 2443-4.

7. This is a transcript prepared in 1917-18 from an old palm leaf MS. belonging to Ampalakkāṭṭu Karunakara Menon, Chalappuram, Calicut.

THE SCIENTIFIC SPIRIT REFLECTED IN INDIAN ASTRONOMY*

Place of Observation in Indian Astronomy

In Indian astronomical tradition the correlation of computation and observation did have a strong base, though this aspect therefore is more often than not understood and appreciated. Obviously, observation preceded computation in the beginning, but this sequence was a zigzag development, with the two alternatives. In the process, parameters were derived and revised, epochs were advanced or taken backwards, zero-corrections were identified and methodologies were changed - all this exercise aimed at rendering the results more and more accurate. Chapters dealing with *Traipraśna, Chāyā* and *Grahaṇa* in the several texts coupled with the composition of a large number of *karaṇa* texts bear this out. The ultimate objective of all these endeavours was, of course, to render computed results correspond with the observed results.

Dṛg-gaṇita in Illustration

The above - mentioned trend would be clear from the introductory verses of the *Dṛg-gaṇita*[1] of the 14th-15th century astronomer Parameśvara (A.D. 1380-1460) of Kerala.

दृश्यन्ते विहगा दृष्ट्या भिन्नाः परहितोदिताः।
प्रत्यक्षसिद्धाः स्पष्टाः स्युर्ग्रहाः शास्त्रेष्वितीरितम्।।१.२।।
सत्कर्मोदितकालस्य ग्रहा हि ज्ञानसाधनम्।
अस्पष्टविहगैः सिद्धः काल्ः शुद्धो न कर्मणि ।।३।।
ये तु शास्त्रविदस्तद्वद् गोलयुक्तिविदश्च तैः।
स्फुटखेचरविज्ञाने यत्नः कार्यो द्विजैरतः ।।४।।
सञ्चिन्त्येति समालोच्य पूर्वतन्त्राणि यत्नतः।
स्फुटयुक्तिं खेचराणां गोलदृष्ट्या समीक्ष्य च ।।५।।

**Purāṇa itihāsa vimarśaḥ (Prof. S.G. Kantawala Fel Vol.)*New Delhi,1998.

स्फुटखेचरविज्ञानं शिष्यैर्यैः प्रार्थितं द्विजैः ।
तेभ्यो दृग्गणितं नाम गणितं क्रियते मया ।।६।।

'Planets computed by the *Parahita* (System of astronomy) are found to be away from their observed positions. According to the science (of astronomy), however, it is stressed that the observed positions alone are the correct positions' (1.2).

'The only means for ascertaining the times for auspicious rites are planetary positions. And, times indicated by incorrect planetary positions are improper for the performance of rituals' (3).

'Hence, by those twice-borns who know astronomy and who are experts in spherics, effort should be made towards ascertaining planetary positions which are true (for observation)'(4).

'Having this in mind, cogitation (on the matter) and after studying earlier treatises in depth and ascertaining the methods (of computing) true planets with the use of (astronomical) instruments, I am composing a work on astronomy by name *Dṛggaṇita* for the use of the twice-born pupils who prayed for the accurate computation of planets' (5-6).

Observation of the Heavens

It would be highly instructive to note how Parameśvara who promulgated his *Dṛggaṇita* system of astronomy in Kerala had striven to evolve the system through astronomical observations. He was a reputed sky-watcher, scanning the sky and recording astronomical phenomena continuously for a number of years. He himself states at one place:

ग्रहेन्द्राः पञ्चपञ्चाशद्वर्षकालं निरीक्षिताः ।
मया, तदा दृशा भिन्ना दृष्टाः परहितोदिताः ।।[2]

'The planets have been scanned by me for fifty five years, their positions as computed through the *Parahita* system were all found to be different (from those observed)'.

Nīlakaṇṭha Somayāji (A.D. 1444-1545), disciple both of Parmeśvara and Parameśvara's son Dāmodara, adds:[3]

परमेश्वरस्तु रुद्र-परमेश्वरात्मजनारायण - माधवादिभ्यो गोलविद्भ्यो गणितगोल-युक्तीरपि बाल्य एव सम्यग् गृहीत्वा तेभ्य एव क्रियमाणप्रयोगस्य दृग्विसंवादं तत्कारणं चावधार्य शास्त्राण्यपि बहून्यालोच्य पञ्चपञ्चाशद्वर्षकालं निरीक्ष्य ग्रहणग्रहयोगादिषु परीक्ष्य समदृग्गणितं करणं चकार।

'Parameśvara imbibed in his younger days, the rationale of mathematics and spherical astronomy from astronomers like Rudra, Nārāyaṇa, son of (another) Parameśvara, and Mādhava (of Saṅgamagrāma). He identified the difference between observed (planetary) positions and those obtained by computation (as taught by earlier authorities) and ascertained the cause of the differences. He thought over the enunciations found in several texts, verified them at the times of eclipses, and, from a consideration of all matters, composed (his) *Dṛggaṇita.*

In the same context, Nīlakaṇṭha mentiones the use by Parameśvara, of astronomical instruments as well. *Cf.*[4]

परमेश्वराचार्येण पुनः ग्रहणग्रहयोगादिकं यन्त्रैः ।
पञ्चपञ्चाशद्वर्षकालं सम्यक् परीक्षितम् ।।

'Parameśvara, too examined the eclipses, planetary conjunctions etc. using astronomical instruments for fifty five years.'

The mention of instruments in this passage is significant.

Observation of Eclipses

In his commentary *Siddhāntadīpikā* on the *Mahābhāskarīya - Bhāṣya* of Govindasvāmin[5], Parameśvara has a long disquisition on eclipses during which he enumerates a large number of controversial eclipses, solar and lunar, which he had observed. He commences this disquisition with the statement :

'तिथिविश्व'समे शाके प्रारभ्य ग्रहणं मया ।
अनेकमीक्षितं, तेषु भिन्नः कालो दृशा सदा ।।२।
प्रत्यक्षकालस्तेषु प्राग् गणितानीतकालतः।
अतः कार्योऽत्र संस्कारो यः कश्चिद् गणकोत्तमैः ।।३।।

'Commencing from *Śaka* 1315 (A.D. 1393), a number of eclipses have been observed by me. In all these, the observed times of occultation was different from the computed ones. In them, the

observed times (of the eclipses) were prior to their computed times. Hence a correction has to be applied to them by astronomers.'

After several arguments and enumerations of eclipses, Parameśvara says; towards the close of this disquisition:[6]

उक्तेभ्योऽन्ये चोपरागा मया दृष्टा विवस्वतः।
इन्दोश्च बहवो दृष्टास्ते तु नोदाहृता इह ।।८६।।
एतानतीतोपरागान् सञ्चिन्त्य परिकल्पिताः।
विलिख्यन्ते मया, भानु-चन्द्र-चन्द्रोच्च-राहवः ।।८७।।

'Many more solar eclipses as also lunar eclipses than those enumerated above have been noticed by me, but they are not set out here. And, I am indicating below the correct positions of the Sun, Moon, Higher Apsis and Node, as determined on the basis of these past eclipses.'

Further down, Parameśvara says[7]:

यदा परहितप्रोक्ता गृह्यन्ते विहगास्तदा ।
कार्यः पूर्वोक्तसंस्कारो यतोऽस्मिन् स्थितिरीदृशी ।।९२।।
कालान्तरे तु संस्कारश्चिन्त्यतां गणकोत्तमैः ।।९३।।

'When the planets etc. are computed according to the *Parahita* School, the above indicated corrections have to be done since the present conditions are as stated above. In future also, similar corrections shall have to be thought of by astronomers'.

The Astronomer's Role

Nīlakaṇṭha Somayāji has produced a unique work entitled *Jyotirmīmāṃsā* ('Investigations on Astronomy'), solely devoted to discussions on astronomical theories, apparent inconsistencies between computed and observed results and enunciation of corrections. He makes some instructive statements on observational astronomy as well.[8]

Stressing the experimental nature of science[9] Nīlakaṇṭha points out that statements in ancient texts about direct instruction by divine beings' do not literally mean that, but only the intellectual inspiration experienced by the 'mortal authors' of the texts, who codified the

results of their experiments and enunciated the astronomical *Siddhāntas*. Mark his words:[10]

ननु 'तपोभिः प्रसन्नो ब्रह्मा आर्यभटाय भगणपरिहयादिकं ग्रहगणनसाधनभूतं संख्याविशेषमुपदिदेश। तदुपदिष्टं पुनरार्यभटः सर्वं यथोपदिष्टमेव दशभिर्गीतिभिर्निबबन्ध' इति केचिन्मन्यन्ते। तस्य कुतः परीक्षणं, ब्रह्मणः सर्वज्ञत्वात्, रागद्वेषाद्यभावाञ्च, अवितथत्वनिश्चयात् इति चेत् - मन्द ! मैवम्। देवताप्रसादो मतिवैमल्यहेतुरेव। न च पुनः ब्रह्मा आदित्यो वा स्वयमेवागत्य उपदिशेत् ।

The methodology of astronomical revision adopted by Nīlakaṇṭha, by observation and experimentation, is unexceptional. He says:[11]

गणितोन्नीतस्य चन्द्रादेः देशविशेषान्वयस्य प्रत्यक्षेण संवादः, ततो निश्चितान्वयस्य परस्य गणितलिङ्गोपदेशः, ततः तस्योपदेशोपगतान्वयस्य अनुमानं, परस्मै चोपदेशः इति सम्प्रदायाऽविच्छेदात् प्रामाण्यम्।

'The correlation of the computed Moon etc. with actual observation at a particular place, the revision of computation on the basis of such correlation, logical inference there from being transmitted as tradition, its being again corrected (through observation and again revised) and transmitted further down to others — this is how tradition is continued without interruption. And this gives continued authoritativeness to tradition.'

Accurately observed eclipses being the most convenient natural phenomena for the verification of astronomical systems and formulation of corrections to current computations, Nīlakaṇṭha advocates this method for the purpose. He says:[12]

अथ सिद्धान्तदीपिकायां उदाहृतानि परीक्ष्यमाणेन गण्यानि। अन्यानि वा ऐतिह्यसिद्धानि स्ववंश्यैरुपदिष्टानि गण्यन्ताम्। एतैः प्रत्यक्षावगतैश्च अनागतग्रहणं निर्णीय वक्तव्यम्। जनपदान्तरजान् तद्देशान्तराक्षादिभिः गणयित्वा रवीन्दुतुङ्गपातान् विज्ञाय अतीतमनागतं स्वदेशजं ग्रहणं स्वदेशाक्षान्तराभ्यां विज्ञातैस्तैरेव ग्रहोच्चपातैर्गणयित्वा निर्णयः।।

'The eclipses illustrated in the *Siddhāntadīpikā* (by Parameśvara) might be computed (in all their details) by the experimentor. Even so, might be computed other eclipses handed down by tradition of one's own school. In the light of these and of eclipses actually observed by the experimenter, future eclipses should be computed and forecast. Or, eclipses occurring at an other part of

the country should be computed using the longitude, latitude etc. of that part of the country and, with that as the basis the True Sun, Moon, Apsis and Node (at the relevant times) ascertained. Then, from the Sun, Moon, Apsis and Node as ascertained as above, past and future eclipses at one's place shall be computed, using the latitude and longitude of one's own place.'

Tradition of Astronomical Revision

There is a highly instructive passage attesting to the advance of astronomy in India through observation and experimentation and consequent revision, from *Dṛkkaraṇa,* an astronomical manual composed in Malayalam verse in A.D. 1607-08,[13] on the advent of the *Āryabhaṭīya*. It says:

paṇṭuḷḷa gaṇitajñanmār connatoṭṭu paraññiiṭām ।
kalyabdam trisahasrattil param cennuḷḷa nāḷilu ।। 1.5 ।।
ottuvanniṭumārilla grahaṇādikaḷ onnumē ।
karaṇaṅṅaḷaum ottīṭā siddhāntaṅṅaḷum ottiṭā ।। 1.6 ।।
tadā hy āryabhaṭo nāma gaṇakas tv abhavad bhuvi ।
'jñānatuṅgeti' kalyabde jātanāyavanītale ।। 7 ।।
'girituṅgeti' kalyabde gaṇitam nirmitam param ।
śāstram āryabhaṭīyākhyam tasmin paryayam uktavān ।। 8 ।।
iva annekkupāyena kuracciṭṭum kareṭṭiyum ।। 12b ।।
kalyādi-dhruvam illāte oppiccān annu paryayam ।। 13a ।।

'Now shall I set out in brief what the early astronomers have recounted. Before *Kali* 3000, the eclipses and other observed results did not tally with the astronomical manuals or the *Siddhāntas*' (5-6).

'Then, in the *Kali* year *Jñānatuṅga* (3600 = A.D. 499) an astronomer by name Āryabhaṭa was born in this world' (7).

'In the *Kali* year *Girituṅga* (3623=A.D. 522) was his work *Āryabhaṭīya* composed and there he stated the revolutions (of the planets).' (8).

'He had adjusted these revolutions by reduction and addition in such a way that there was no zero-correction at the beginning of *Kali*.' (12b-13a).

pinne igganitattinnu nīkkam kaṇṭitu bhūtale ।
'mandasthale' ti kalyabde 'tanute' ti śakābdake ॥ 18 ॥
palarum gaṇitajñanmār kūṭe nokkīṭṭu veccatu ।
kalyabdād 'girituṅgo' nāt śeṣam veccu perukkaṇam ॥ 19 ॥
pērum Parahitam ennu, gaṇitam sūkṣmam ennitu ।
iti niścitya palarum ācariccavanītale ॥ 25 ॥

'In course of time, deviations were observed in (the results arrived at by) this computation'. (18a).

'Then, in the *Kali* year *mandasthala* (3785=A.D. 684), equivalent to *Śaka tanutā* (606), several astronomers gathered together and derived by observation, (a system), wherein (the correct number of revolutions were to be found) by multiplying the current *Kali* year minus '*girituṅga*' (*Kali* 3623, viz., the Āryabhaṭan epoch) (by the yearly *Bhaṭābda* or *Śakābda* corrections enuciated) (18b-19)

'This system was termed "*Parahita*" and many followed it, being assured of its accuracy:' (25)

cirakālam kazhiññappol nīkkam vaḷare vannitu ।
'raṅgaśobhā'nu kalyabde kaścid vipravaras tadā ॥26॥
paścimambodhi-tīrathu ninnu nokkīṭṭu vaccatu ॥27a॥

'When a long time had elapsed, there occurred substantial deviation.' (26a)

'Then, a noble Brahman, residing by the western ocean revised it (i.e., the *Parahita* system) by means of (astronomical) observations, in the *Kali* year *Raṅgaśobhā* (4532 = A.D. 1431).' (26b-27a).

dvādaśābdam kaḷiññiṭṭu tantrasaṅgraham ennatu ॥27b॥

'Twelve years later (occur the planetary revolutions depicted in) the *Tantrasaṅgraha*'. (27b).

tasmin paryayavum pinne sthūlamāyiṭṭu colliyāl ।
'jasustave' ti kalyabde tuṭarnnār avanītale ॥28॥
paścimāmbodhitīrattu ninnu muppatu varṣavum ।
nokkīṭṭu gaṇakanmārum 'janasevā nu vatsare ॥29॥
sūkṣmam varutti nirmiccrār gaṇitāgamam annavar ।
iniyum kaṇṭukoḷḷeṇam cirakālād varunnatu ॥30॥

'The revolutions given therein (i.e in *Tantrasaṅgraha)*, too, being stated to be inaccurate, observations were continued by the astronomers on the west coast for thirty years, from the *Kali* year *jasustava* (4678 = A.D. 1577) to th *Kali* year *janasevā* (4708 = A.D. 1607) and by observation the astronomical tradition was revised accurately' (28-30a).

'Henceforward, too, (the deviations) that would occur should be carefully observed' (and appropriate revision effected) (30b).

Now, one need not doubt the varacity of these statements, for the parameters mentioned in the *Dṛkkaraṇa* are corroborated by the different texts referred to therein. Neither is the continuous scanning of the sky for years together, for astronomical purposes, surprising for it is done even today. It is also valid that, for limited purposes, simple instruments or even the naked eye is sufficient. As an illustration, might be cited the case of Gaorge Alcock, an English sky - watcher of today, who has been watching the skies from 1924 with a simple pair of binoculars, and forestalled even the worlds' observatories in spotting a nova and four comets which bear his name.[14]

Magna Carta for Astronomical Standardisation

In the light of the above disquisition, the *Jyotirmīmāṃsā* of Nīlakaṇṭha Somayāji provides what might be termed as the *Magna Carta* in the matter of 'Standardising and modernizing the Indian *Pañcāṅga*', being the theme of the endeavours of the Rashtriya Veda Vidya Pratiṣṭhan, New Delhi. In the *Jyotirmīmāṃsā,* Nīlakaṇṭha poses the situation of a system of astronomy getting outdated and outmoded and asserts categorically that it is perfectly justified to revise and even to discard an old system which is defective and replace it by another which is true to observation. The relevant statement begins with a *pūrvapakṣa* ('opposer's view):

ननु 'पैतामहादिभेदेन परस्परविरुद्धाश्च सिद्धान्ता भवन्ति। सिद्धान्तभेदे सति कालभेदः। कालभेदे सति कालाङ्गानि श्रौतस्मार्तलौकिकानि कर्माणि विकलानि स्युः। कर्मवैकल्ये सति लोकयात्रोच्छेदः। हा धिक् ! सङ्कटे महति पतिताः स्मः।' (*Jyotirmīmāṃsā*, p. 6)

The opposing contestant observes: 'There arises the vexing question that there are astronomical *Siddhānta*s like *paitāmaha* (and others) which are mutually different. When there are differing

Siddhāntas, the time (date). If one follows different times (the performance of) Vedic, domestic and social rites and rituals which depend upon (their performance at proper) times will get distorted. When there is distortion of rituals there would ensue termination of life. Alas! We have fallen into a great catastrophe'.

In the face of this possible catasphere, Nīlakaṇṭha offers the mitigation:

अत्रोच्यते - 'ऋजुमते ! स न शोचितव्यः। गुरुचरणपरिचरणपरैः किमिव न ज्ञायते। पञ्चसिद्धान्तास्तावत् क्वचित्काले प्रमाणमेव इत्यवगन्तव्यम्। अपि च यः सिद्धान्तो दर्शनाविसंवादी भवति सोऽन्वेषणीयः। दर्शनसंवादश्च तदानीन्तनैः परीक्षकैर्ग्रहणादौ विज्ञातव्यः। ये पुनरन्यथा, प्राक्तनसिद्धान्तस्य भेदे सति, यन्त्रैः परीक्ष्य ग्रहाणां भगणादिसंख्यां ज्ञात्वा अभिनवसिद्धान्तः प्रणेय इत्यर्थात्। तत् त इहलोके अहसनीयाः, परलोके अदण्डनीयाश्च इति।' (*Jyotirmīmāṃsā*, p. 6)

Now here is the solution: 'You simpleton! Such a situation is not so despairing. What is there which is not known to those who are devoted to the service (and understanding) of their teachers. It is to be realized that the five *Siddhāntas* (in Varāhamihira's *Pañcasiddhāntikā*, and also other *Siddhāntas*) are valid only for a limited time. Therefore one has to be on the look out for such a *Siddhānta*, which is true to observation (during one's own times). Correspondence (of computed times) to observed times should have to be ascertained contemporary observers during times of eclipses etc. When the two differ, that is, when an earlier system does not correspond to observation, one should conduct experiments using (astronomical) instruments, and ascertain (afresh) the revolution numbers of the planets. And, *a new Siddhānta* (which corresponds to observation) should be expounded. For doing this, such (expounders) will not be laughed at in this world; neither will they get punished in the next world.'

NOTES AND REFERENCES:

1. Ed. K. V. Sarma, Hoshiarpur, 1963.
2. Quoted by Nīlakaṇṭha Somayāji in his *Āryabhaṭīya-bhāṣya* on 4.48, Trivandrum, 1957, p. 157.
3. *ĀBh. Bhāṣya* on 4.48, edn. Trivandrum, 1957, p. 154.
4. *op. cit.* p. 54.
5. Ed. Madras, 1953, pp. 321-22.
6. *ibid*, p. 331

7. *ibid*, p. 332
8. Cr.' Ed. and published (K. V. Sarma, Hoshiarpur, 1977).
9. *op. cit.*, pp. 1-2.
10. *op. cit.*, p. 2
11. *op. cit.*, p. 3.
12. *Jyotirmīmāṃsā*, pp. 31-32.
13. Ms.: No. C. 7c of the Kerala Univ. Or. Mss. Library, Trivandrum.
14. The following Reuter's news item bearing the date Dec. 6., 1976, should be instructive: LONDON, Dec. 6 (Reuter). On a small ridge in rural eastern England lives a 64 year old primary school teacher who may know more about the night skies than any other man alive.

George Alcock, lying on an old deck chair in his backyard and using a simple pair of binoculars, recently spotted a Nova, an exploding star. What makes the incident so spectacular that he saw it before all the world's professional astronomers with their huge telescopes and complex photographic equipment.

After Mr. Alcock saw the Nova he got in touch with other amateurs in the British Astronomical Association who verified his discovery. They cabled the news to astronomy's central clearing house at the Astrophysical Observatory in Cambridge, Massachusetts.

Thanks to Mr. Alcock's quick work, Dr. Eugene Harlan at Lick Observatory, California, who was able to analyse the star that same night as it approached maximum intensity. Mr. Alcock is an amazing man, the sort of dedicated, lonely eccentric upon which England prides itself.

He has been watching the skies since 1924, when astronomers were seeing what looked like artificial canals on the surface of Mars.

Then in the 1940s he decided to set up a comet watch, and improve the reputation of England's astronomers, who had not spotted a comet first since 1894.

Six years after that decision the first comet was named after him, and he has since got three more bearing his name.

SAWAI JAI SINGH AND HIS CONTRIBUTION TO INDIAN ASTRONOMY*

The *Kāśi-mānamandira-vedālaya-varṇanam*, 'Description of the observatory at Mānamandira in Kāśi', is a unique document of scientific writing in Sanskrit of the 19th century, in as much as it forms a first-hand account by Pt. Bapudeva Shastri (1820-1889, Professor of Astronomy at the Banares Sanskrit College), of the outdoor observatory of massive astronomical instruments erected in A.D. 1737 by Mahārājā Sawāi Jai Siṃha of Jaipur (1686-1743), on the terrace of Mānamandira, a palace built by his ancestor Mahārājā Māna Siṃha (1550-1614) near the *Maṇikarṇikā ghāṭa* on the Ganges at Varanasi (lat. 25°18'N, long. 83°1' E). Dr. S.D. Sharma, who has edited this work, which had long been out of print, adding to it an informative Introduction, a readable Translation and elucidatory Notes, richly deserves credit for his efforts in this direction.[1]

The remarkable life of the scholar prince Jai Singh is not altogether unknown, but it deserves to be known better. It may not be out of place, therefore, to notice here briefly the more important facets of his many-sided activities so as to form a back-drop for a study of the present work, *Kāśi-mānamandira vedālaya-varṇanam*.

A scion of the royal house of Amber in Rajasthan, Jai Singh was the elder son of Maharājā Viṣṇu Siṃha (1671-99). Even from his young age Jai Singh exhibited extraordinary sagacity and intelligence. According to tradition, the prince had a comprehensive education in the arts and sciences, but he remained a student throughout his life, expanding his knowledge and putting it to practical use. In A.D. 1696 he was sent to the court of the Mughal emperor Aurangazeb, who was then camping at Aurangabad in the Deccan. In 1698 Jai Singh won the Khelna fort for the emperor who conferred on him the title 'Sawai', meaning that he was equal to 'one and a quarter' of others. Soon

*A foreword by K.V. Sarma to the book *Mānamandira Observatory of Kāśī* by Bapudeva Sastri, Punjab, 1982.

after his return from the Deccan, his father Viṣṇu Siṃha passed away and Jai Singh ascended the throne in 1699. For the next forty-four years, till he passed away in 1743, Jai Singh remained in the thick of State affairs and imperial politics, playing significant roles as administrator, military general, diplomat, advisor and mediator at the highest levels. He lent his services to five contemporary Mughal emperors, including Aurangazeb (1658-1707), Bahadur Shah (1707-12), Jahandar Shah (1712-13), Farruksiyar (1713-19) and Muhammad Shah (1719-48). He earned imperial approbation for his campaigns in the Deccan, for crushing the rebellion of the Rohillas and the Jats, and for diplomatic dealings with the Rajputs and Marathas. In the home front, he instilled, in the minds of the discordant rulers of Rajasthan, a spirit of nationalism and created a strong confederacy of Rajputs, the several rulers being imbued with a sense of self-dependance and mutual alliance, though remaining under the suzerainty of the Mughal emperor. In recognition of his qualities of head and heart Muhammad Shah made him, in 1719, the Governor of the provinces of Agra and Malwa, which office he held with distinction till his death in 1743. It is from the aforesaid background of hectic political and military life which he had to lead, often far from his state capital that the achievements of Jai Singh in the literary, cultural and scientific fields have to be assessed.

As shrewd observer of the political trend of the times, Jai Singh could foresee that the Mughal Empire was declining fast and so it was up to him and others like him to establish themselves on their own. Therefore, alongside continuing as a Governor of the Mughals, Jai Singh expanded his territories and consolidated his position and induced the other Rajput chieftains also to do likewise. He placated the Marathas and restricted their advance to the north. He felt his ancestral capital of Amber to be too small to serve as the capital of a big State and so built, in a strategically secure valley, a few miles away, an extensive and well planned city called after his name as Jayanagar or Jaipur to serve as the new capital of the State. Thus consolidating his position politically, Jai Singh extended his activities also in the academic sphere, mainly in the disciplines of astronomy,

literature and religion. It is interesting that besides engaging himself personally in such studies, Jai Singh attracted to his court stalwarts in these disciplines even from far off lands and enthused and patronised them in these studies under his direction.

What Mahārājā Jai Singh is popularly known is for the impact which he gave to comparative and practical studies in astronomy. His early inculcation into the science is evidenced by the presence of manuscripts on the subject preserved in the Palace Library at Jaipur wherein it has been inscribed that they were specially copied for his study.[2] In Rājaguru Samrāṭ Jagannātha Paṇḍita from Maharashtra, he had a learned preceptor who stimulated his interest in astronomy and initiated him in the intricacies of the science.[3] Jai Singh collected for his study all important works on astronomy and mathematics in Sanskrit, Arabic, Persian, Latin, French and English,[4] including the works of La Hire, the French astronomer, Flamsteed, Royal astronomer of England at Greenwich and P. Gaubil (observations Chinoise, 1732), on the one hand, and works like Zich Ulughbeghi by Mulla Chand, Sharah Zich-Mirza Ulughbegh, Jamshed's Zich-Khagani etc., on the other.

Jai Singh invited to his court some of the eminent exponents of Hindu and Muslim schools of astronomy to learn from them and towards inducing them to compose original works and prepare translations in Sanskrit of Arabic works and European writings. His courtiers included the Portuguese Jesuit, Padre Manuel Figuaredo, a student of Western science, whom, he later sent, with some Hindu assistants, to collect more astronomical tables, books and other material on Western advances in astronomy. It is equally interesting that the King of Portugal responded royally by sending to Jai Singh's court one of his astronomers, Xavier de Silva, with the latest books on European astronomy. Comparative study and correlation of the three streams of astronomy, Hindu, Arabic and European, is one of the main achievements of Jai Singh's endeavours.

The labours of Jai Singh in the field of astronomy can be divided into three phases. He noted that Hindu astronomy, to which he was initiated first, derived the results mostly through computation

from early constants and later corrections. Practical minded that he was, Jai Singh was naturally attracted to the astrolabe and other metallic instruments of the Muslim school, for astronomical observations could be made and results read off directly through them. In this wake, he ordered the preparation of similar instruments adapted to the Hindu school which would give the results in terms of Hindu astronomy. A number of these instruments are still preserved in museums and other repositories in Jaipur, Banaras and elsewhere.[5] However, detailed experimentations made it clear to Jai Singh that though these instruments were handy, they suffered from serious limitations on account of their smallness, wear and tear, and effect on them of the weather.

The said realisation led Jai Singh to the second phase of his endeavours, which consisted of erecting outdoor observatories with massive instruments of stone and masonry. He took the cue for this from the huge observatories which had been erected in Central Asia by Ulugh Beg (1394-1449) in Samarkand and by others elsewhere. He built his first observatory in 1724 in Delhi, the Mughal capital, to be followed by observatories in his own capital Jaipur(1734), and at three major Hindu centres of pilgrimage on the banks of holy rivers, where scholars and cultured people would congregate and make profitable use of the observatories, viz., at Ujjain (1734) on the bank of river Kṣiprā, at Varanasi (1737) on the Ganges, and at Mathura on the Yamunā. Some of the instruments installed here were modelled on earlier counterparts, while others were devised by Jai Singh himself. A manuscript entitled *Yantraprakāra* preserved in the Art Gallery as No. 31 at the Mahārājā's Jaipur Museum, mentions the undermentioned astronomical instrumnents designed by Jai Singh, in the sixth section of the work, with the caption: *Śrī-mahārājādhirāja-viracita-yantrāṇi*: (1) *Jayaprakāśa-yantra*, (2) *Nāḍī-valaya*, (3) *Krāntivṛttam*, (4) *Palabhā-yantram*, (5) *Digaṃśayantram*, (6) *Śarayantram*, (7) *Agrāyantram*, (8) *Yāmyottaramiti*, (9) *Jātulahalaka*, (10) *Yantrarāja*, (11) *Jātuśukavataina*, (12) *Sudasphakari*, (13) *Jātuśukataina* (14) *Śaṅkuyantra* and (15) *Pratirāśīṇām krāntivṛttam*. Some of these instruments and some more are found to be installed in the different observatories constructed by

Jai Singh.[6] While most of these are adaptations, with improvements, of earlier counterparts, three, especially, found in the observatories, are supposed to be invented by Jai Singh; they are: *Jayaprakāśa*, named after himself, *Rāma-yantra*, named after his grandfather Rāma Singh and *Samrāṭ-yantra* named after his preceptor Samrāṭ Jagannātha Paṇḍita.[7]

The third phase of Jai Singh's labours arose in the wake of th limitations of the said outdoor observatories. Stable and accurate as they were, weather conditions including rains, clouds and darkness, and lack of accessibility to all at all times came in the way of their utility. Moreover, determination of past and future phenomena was impossible from observatories. These considerations made Jai Singh to think of astronomical tables based on observations made at these observatories. Towards this he studied several astronomical tables prepared on the basis of direct observation of the celestial bodies in the observatories of Central Asia, including the Īlkhāṇīc Tables of Nasī al-Dīn-Tūsī prepared at *Marāgha* observatory in North-West Persia, founded in A.D. 1259, and the 'Tables of Stars' compiled by Ulugh Beg at the observatory of Samarkand. Correlating these tables with the periodical observations made at his own observatories; Jai Singh prepared a set of astronomical tables which he called Zīj Muhammad Shāhi in the name of his suzerain, the Mughal emperor Muhammad Shāh (1719-48). This work is available both in its Sanskrit and Persian versions.[8] The following extracts from an English translation of the Introduction to Persian version of the *zīj Muhammad Shāhī* would reveal, as nothing else would, Jai Singh's line of thought in this matter.[9]

'Praise be to God... ...From inability to comprehend the all-encompassing beneficence of His power, HIPPARCHUS is an ignorant clown who wrings the hands of vexation; and in the contemplation of His Exalted Majesty, Ptolemy is a bat, who can never arrive at the sun of truth : the demonstrations of EUCLID are an imperfect sketch of the forms of his contrivance ; and thousands of JAMSHID KĀSHĪ,[10] or NASĪR TŪSĪ [11] in this attempt would labour in vain.

'But since the well-wisher of the works of creation and the admiring spectator of the theatre of infinite wisdom and providence SAWAI JAI SINGH,[12] from the first dawning of reason in his mind and during its progress towards maturity, was entirely devoted to the study of mathematical science, and the bent of his mind was constantly directed to the solution of its most difficult problems, by the aid of the Supreme Artificer he obtained a thorough knowledge of its principle and rules.

'He (Jai Singh) found that the calculation of the places of the stars as obtained from the tables in common use, such as the new tables of SA'ĪD GURGĀNĪ[13] and KHĀQĀNĪ[14], and the Tasahīlāt-Mula Chānd Akbar Shāhī,[15] and the Hindu books, and the European tables,[16] in very many cases give them widely different from those determined by observation; especially in the appearance of the new moons, the computation does not agree with observation.

'Seeing that very important affairs both regarding religion and the administration of empire depend upon these; and that in the time of the rising and setting of the planets, and the seasons of eclipses of the sun and moon, many considerable disagreements of a similar nature were found-he represented it to his Majesty of dignity and power,...MUHAMMAD SHĀH [17]. May he ever be triumphant in battle.[18]

'He was pleased to reply, 'Since you, who are learned in the mysteries of science, have a perfect knowledge of this matter, having assembled the astronomers and geometricians of the faith of Islām, and the *Brāhmaṇas* and *Paṇḍitas*, and the astronomers of Europe, and having prepared all the apparatus of an observatory, do you so labour for the ascertaining of the point in question, that the disagreement between the calculated times of those phenomena, and the times which they are observed to happen, may be rectified.'

'Although this was a mighty task, which, during a long period of time, none of the powerful Rajas had prosecuted; nor among the tribes of Islām, since the time of the martyr prince, whose sins are forgiven, MIRZA ULUGH BEG, to the present which comprehends a period of more than three hundred years,[19] had any one of the kings

possessed of power and dignity turned his attention to this object. Yet to accomplish the exalted command he had received, he bound the girdle of resolution about the loins of his soul and constructed here [20] several of the instruments of an observatory, such as had been crected at Samarqand,[21] agreeable to the Mussalman books, such as Zāt al-Halqa[22] of brass, in diameter three gaz[23] of the measure now in use and Zat al-Sha'datain[24] and Zāt at-Zaqatain and Sads [25]Fakhri and Shāmalah.'[26]

'But finding that brass instruments did not come up to the ideas which he had formed of accuracy, because of the smallness of their size, the want of division into minutes, the shaking and wearing of their axes, the displacement of the centres of the circles, and the shifting of the planes of the instruments, he concluded that the reason why the determinations of the ancients, such as HIPPARCHUS and PTOLEMY, proved inaccurate, must have been of this kind.'

'Therefore he (Jai Singh) constructed in Dār al-Khilāfat Shāh Jahānābād, [27] which is the seat of empire and prosperity, instruments of his own invention, such as *Jai Prakāś* and *Rām Yantra* and *Samrāṭ Yantra*, the semidiameter of which is of eighteen cubits and one minute on it is a barley corn and a half [28] of stone and lime of perfect stability, with attention to the rules of geometry and adjustment to the meridian and to the latitude of the place, and with care in the measuring and fixing of them, so that the inaccuracies from the shaking of circles and wearing their axes and displacement of their centres and the inequality of the minutes might be corrected. Thus an accurate method of constructing an observatory was established and the difference which had existed between the computed and observed places of the fixed stars and planets by menans of observing their mean motions and observations was removed.'

'And, in order to confirm the truth of these observations, he constructed instruments of the same kind in Sawāi Jaipur, Muttra (present Mathura) and Beṇares and Ujjain.[29] When he compared these observatories, after allowing for the difference of longitude between the places where they stood, the observations agreed...'

'But seeing that in many cases it is necessary to determine past or future phenomena: and also that in the instant of their occurrence cloud or rain may prevent the observation or the power and opportunity of access to an observatory may be wanting the deemed it necessary that a table be constructed by means of which the daily places of the stars being calculated every year and disposed in calendar may always be in readiness.'

'In the same manner as the geometers and astronomers of antiquity bestowed many years on the practices of observation thus, for the establishment of a certain method, after having constructed these instruments, the places of the stars were daily observed.'

'After seven years had been spent in this employment, information was received that about this time observatories had been constructed in Europe[30] and that the learned of that country were employed in the prosecution of this important work; that the business of the observatory was still carrying on there and that they were constantly labouring to determine with accuracy the subtleties of this science.'

'For this reason, having sent to that country several skilful persons along with PADRE MANUEL,[31] and having procured the new tables which had been constructed there thirty years before and published under the name LIR,[32] as well as the Europe tables anterior to those.'[33]

'On examining and comparing the calculations of these tables with actual observations it appeared that there was an error in the former in assigning the moon's place of half a degree. Although the error in the other planets was not so great, yet the times of solar and lunar eclipses he found to come out later or earlier than the truth by the fourth part of a *ghaṭi* or fifteen *palas*.'[34]

'Hence he concluded that, since in Europe astronomical instruments have not been constructed of such a size and so large diameters, the motions which have been observed with them may have deviated a little from the truth.'[35]

'Since in this place by the aid of the unerring Artificer astronomical instruments have been constructed with all the exactness that the heart can desire and the motions of the stars have, for a long period, been constantly observed with them agreeable to observations, mean motions and equations were established; he found the calculation to agree perfectly with the observation. And although to this day the business of the observatory is carried on, a table under the name of His Majesty, the shadow of God, comprehending the most accurate rules, and most perfect methods of computation was constructed; so that, when the places of the stars and the appearance of the new moons and the eclipses of the sun and moon and the conjunction of the heavenly bodies are computed by it, they may arrive as near as possible at the truth, which, in fact, is every day seen and confirmed at the observatory....'

The *Zīj Muhammad Shāhī*, prepared on the basis of the data recorded through extensive daily observations for over seven years, is available in two versions, entitled *Zīj-I-Muhammad Shāhī*, 'Astronomical Tables of Muhammad Shāh, (Ms. Raza Library, Rampur, No. 1221) and *Zīj-i-Jadid Muhammad Shāhī*, '*New Astronomical Tables of Muhammad Shāh*' (Ms. British Library, London, No. 14373). The *Zīj* is prepared, among other things, so as to serve as an accurate almanac both for Hindus and Muslims, and is patterned after Zīj-i-Ulaghbegi (*Cf.*Ms. India office, London, cat No. 2233). It is divided into three sections: (i) Rules for the mutual transformation of the four calendars, Hijari, Muhammad Shāhī (introduced in the name of Muhammad Shah in Hijari 1131), *Vikram Saṃvat* and Gregorian, in four chapters; (ii) measurement of time, in nineteen chapters; and (iii) Motions of stars and planets and their position from a certain longitude and latitude etc., in five chapters. It may be noted that while star tables in the earlier version (Raza Library) takes note of 60 stars only, the later version (British Library) takes note of 1018 stars. It is again of interest to note that in Northern India annual almanacs continued to be computed on the basis of the *Zīj* for more than a century following its composition.[3]

Politics and astronomy were, indeed, not the only avocations of Jai Singh. His active interest extended to other spheres, as well. He led a religious life, with all its attendant rites and rituals. He performed royal sacrifices and gave away large gifts, as stated by himself in the beginning of his commentary *Brahmabodhinī* on the *Bhakti-sūtras* of Vyāsa. *Cf.*:

कृतषोडशदानेन सर्वतोमुखयाजिना
वाजपेयाग्निचयनसप्तसंस्थाविधायिना ।
महाराजाधिराजेन जयसिंहेन धीमता
सूत्रवृत्तिः पवित्रेयं ग्रथिता ब्रह्मबोधिनी ।।

As a staunch devotee of Lord Kṛṣṇa, Jai Singh invited to his court exponents of the different schools of Vaiṣṇavite persuasions like those of Rāmānuja, Madhva, Nimbārka, Vallabha and Caitanya, and had them hold discussions. He also endeavoured to reconcile their different views and evolve a common approach. He built new temples, including the famous Govindaji temple in Jaipur, and preserved the old ones. Several philosophical and devotional works were composed during his reign. He also patronised erudite scholars in *Veda* and *Dharmaśāstra*, and also poets, both in Sanskrit and local dialects. It is highly instructive to note that Jai Singh established, near his capital, a 'Scholars village', by name Brahmapurī, where he settled some of the scholar invitees.[37] Indeed, a substantial quantum of literature was produced during Jai Singh's reign and Jaipur shone as a centre of learning in all Rajasthan.

NOTES AND REFERENCES:

1. A later account by G.R. Kaye, has been appended to this edition from Kaye's book, *The astronomical observatories of Jai Singh*, (Calcutta,1918), towards facilitating a comparative study.

2. E.g., the manuscript of *Bhāsvatī* (MS.No.5195) and Vārāhīsaṃhitā (MS.No.5569), both copied in Sam.1758 (A.D. 1702), when Jai Singh was sixteen, carrying the post-colophonic inscription to the effect that they were copied for his study.

3. It is interesting to note that Jagannātha also officiated in the ceremonies at the founding of the new capital Jaipur in 1728.

At the instance of his patron, Jagannātha translated into Sanskrit Euclid's Elements of Geometry in his *Rekhāgaṇita* and Ptolemy's Almagest in his *Samrāṭ-Siddhānta*.

4. For a list of books in the European languages and in Arabic and Persian procured by Jai Singh for the Khasmohar Section (i.e., the section of the Palace Library kept under the personal seal of the royalty), see G.N. Bahura, *Literary heritage of the rulers of Amber and Jaipur*, (Jaipur, 1976), pp.55-56.

5. See also G.R. Kaye, The astronomical observatories of Jai Singh, (Calcutta, 1918), Ch.V. 'Hindu metal instruments', pp. 31-34.

6. E.g., the manuscript of *Bhāsvatī* (Ms.No.5195) and *Vārāhisaṃhitā* (Ms.No.5569), both copied in *Sam* 1758 (A.D. 1702), when Jai Singh was sixteen, carrying the post-colophonic inscription to the effect that they were copied for his study.

7. For detailed accounts of these observatories and the astronomical instruments installed therein, see G.R. Kaye, The astronomical observatories of Jai Singh, (Calcutta, 1918), pp. 41-68; and Prahlad Singh, Stone observatories in India, (Varanasi, (1978), pp. 183-209.

8. Mss. of both versions are available in the Palace Library, Jaipur. Of the Persian version, a dozen copies are known, preserved in British Library, London, Cambridge University Library, Tashkent Oriental Mss. Library, Maulana Azad Library, Aligarh, Sawai Man Singh II Museum, Jaipur, Bankipur Library. Patna and Raza Library, Rampur. For a general study on the work, see Virendra N. Sharma, '*Jai Singh and his Zij-i-Muhammad Shahi*', being a paper presented at the Conference of South Asian Studies, University of Wisconsin, Madison, Oct. 1979.

9. Extracted from W. Hunter, '*Some account of the astronomical labours of Jayasinha, Rajah of Ambhere or Jayanagar*', Asiatick Researches, 5 (1799) 117-211, (see p. 178 ff.), and reproduced by G.R. Kaye, *The astronomical observatories of Jai Singh*, (Calcutta, 1918), pp. 10 ff.

10. Jamshid b. Mas'ud Gijāt al-Din al-Kashi was one of Ulugh Beg's astronomers.

11. Nasir al-Din al-Tūsī was born A.D. 1201. He worked at the *Marāgha* observatory and published the famous 'Ilkhāṇic Tables'. He translated Euclid's Elements and Ptolemy's Almagest, and wrote many works on astronomy.

12. Jai Singh writes in the third person.

13. Possibly 'Ali b.M. Al- Saijid Al-Sarif Al-Gurgānī, who lived from A.D. 1339 to 1414 in Shiraz, and wrote a commentary on Nasir al-Tūsī's *Tadkira* (See H. Suter's *Die Mathematiker und Astronomender Araber und Ihre Werke*, p.172) : but *Gurgānī* was a designation of Ulugh Beg's family, and Ulugh Beg's tables were sometimes termed the *Gurgānī* canon (See L.P.E.A Sedillot's Prolegomnes des Tables astronomiques d'Oloug Beg, p.c.xix ; also Āin-i-Akbari, (iii) 20 and 41 (Jarrett's edition) ; *Akbarnāmā*, (i), 204 (Beveridge's Edition).

14. Suter (p.95) mentions one al-Khāqānī, an astronomer and astrologer, who died in A.D. 1038 and who worked at improving the astronomical tables. The Khāqānī tables were supplementary to the Ilkhānic tables of Nasīr al-Tūsī and were prepared and edited by Jamshīd al-Kāshi.

15. Maulānā Chānd, the astrologer, who was possessed of great acuteness and thorough dexterity in the science of the astrolable, in the scrutinising of astronomical tables, the construction of almanacs and the interpretation of the stars, was deputed to be in attendance at the portals of the cupola of chastity in order that he might observe the happy time and ascertain exactly the period of birth (of Akbar). He reported in writing to the exalted camp that according to altitudes taken by the Greek Astrolable and by calculations based on the Gurgānī tables, etc. (*Akbarnāmā*. Vol.I. 69-70. Ed. Beveridge). He also cast the horoscope of Jahāṅgīr in A.D. 1570 according to the Greek canon (ib, ii, 506-7; see also i, 56 and 374).

16. He is possibly referring to La Hire's *Tabuloe Astronomicoe and Flamsteed's Historia Coelestis Britannica*.

17. Muhammad Shāh reigned from 1719-1748.

18. This must have been written before 1739 when Nadir Shah sacked Delhi.

19. Ulugh Beg was assassinated in A.D. 1449 while the *Zīj Muhammad Shāhī* is supposed to have been published in 1728, approximately 297 Muslim years after.

20. At Delhi.

21. We have very little information about the observatory at Samarqand. Greaves stated that the quadrant used by Ulugh Beg was as high as the summit of St. Sophia at Constantinople, or about 180 feet. The earlier Muslim astronomers had also devised huge instruments. In A.D. 995 Abu-l-Wafā used a quadrant of radius 21 feet 8 inches; al-Khojendī used a sextant with radius 57 feet 9 inches. Nasīr al-Din set himself the task of perfecting instruments, etc. See Sedillot's Prolegomnes des Tables astronomiques d'Ouloug Beg, p. cxxix.

22. A ring instrument, armilla, sphaera armillaris (Nallino ii.329).

23. 3 gaz = 9 feet ordinarily, but perhaps here a gaz = 1 daṇḍa = 6 feet approximately.

24. An astrolabe with two rings or parts. It is the triquetrum or regulae parallacticae. Al-Battānī calls it the 'long alhidade' (Nallino i.321). In Leiden is a Ms. De ratione qua ope instrumenti Zat al-Sho'batain, etc. by the celebrated al-Kindī. Muhammad bin Ishāq b. Abī Abbād, Adu'l-Hasan also wrote on the same instrument (Suter, pp. 25 and 48)

25. This must be the same as the *Shashtāṃśa Yantra*, which according to Jagannāth, 'the Yavanas called shudsufkari.'

26. The *Jai Prakāśa* is called *Shamlah* by Hunter.

27. i.e., Delhi.

28. To make the measurements fit, the cubit used must have been a large cubit 36 *aṅgula*s.

29. This implies that the Delhi observatory was completed before the others were started; and that all of them were built before the Preface was written. This dates the Preface after 1734 and perhaps after 1737.

30. Uraniborg (Tycho Brahe's observatory) in 1576; Leiden 1632; Paris 1667; Greenwich 1675; Berlin 1705; St. Petersburg 1725; Upsala 1730, etc.

31. In 1728 or 1729 the Reverend Father Figueredo, a Portuguese Jesuit, went to Europe by the order of Jai Singh. Possibly this is the same man. See Lettres edifiantes et curieuses, XV, 269.

32. La Hire's Tabulae Astronomicoe was published in 1702. Father Boudier, who went to Delhi and Jaipur in 1734. actually refers to this edition. He writes: "En se servant de la méthode de M de la Hire, edition de ses tables 1702, page 53, on a trouvé que le commencement de l" éclipse a Delhi, lorsqu'il était á Rome 11 heures 40 minutes 55 seconds du matin, etc," Lettres, etc., XV. 288.

33. We know that, besides La Hire's tables, Jai Singh possessed those of Ulugh Beg and Flamsteed. The latter's work contains also the tables of Tycho Brahe, the Landgrave Hesse, and Hevelius. Other possible tables are the Toletan Table of 1080; the Alfonsine Tables, 1252; Reinhold's Prussian Tables, 1551: Kelpler's Rudolphine Tables, 1627; Qassini's tables 1668 and 1693; Halley's table, 1719; etc.

34. 60 *palas* =1 *ghaṭi* = 24 minutes, and 15 *palas* = 6 minutes.

35. The instruments used by Flamsteed (1646-1719) were an iron sextant of 6 feet radious; a three foot quadrant; a mural arc of 140 degrees and radius 7 feet, 'divided with hitherto unapproached accuracy.' and with which all his most valuable work was executed; two clocks and two telescopes.

36. For a detailed account of the Zīj, see Virendra N. Sharma, loc. cit. to whom I am indebted for the information given above.

37. For an account of this village, see K.V. Sarma, '*Brahmapuri, the scholars village established by Maharaja Sawai Jai Singh*', *Rajasthanica*, (Jaipur), vol.I (1982), pt.i.

SCIENTIFIC TEXTS IN SANSKRIT IN AID OF MODERN SCIENCE*

I. *Introductory:*

An aspect of Sanskrit, which yet remains to attract the full attention it deserves, is the fund of scientific data therein, which could lead to further development even in modern science. Two factors, especially, conduce to the viable richness of scientific matter in Sanskrit literature. First, it has an unbroken literary tradition commencing from at least the third millennium B.C. from when the Vedic hymns were composed, to be later redacted and arranged into the presently current four *Veda*s in their several recensional *Saṃhitā*s. Casual mention and sometimes specific details occur herein of the scientific acumen of early India down the ages. Secondly, there are a number of systematic texts on several scientific disciplines including Mathematics and Astronomy, Medicine, Alchemy, Agriculture and Architecture. A study in detail of the literature cited above would, naturally, give a fair idea of the development of science in early and medieval India. But what is of particular interest is that it gives also a clue to its potential for the furtherance of modern science and necessity for a study of Sanskrit by modern scientist towards exploiting that potential.

II. Mental Make-up of the Indian Scientist:

A marked difference might be noticed, from early times, between scientific documentation as practiced in West, and in the East. The Western practice exhibits extravortism while the Eastern practice exhibits intravortism. In the West, the practice of setting out scientific data and results step by step, in detail, and in logical form had been the norm even from the times of Aristotle (384-322 B.C.), Euclid (c.360 B.C.) and Ptolomy (c. 168 B.C.). Medieval scientists of Central Asia like Al Khowarizimi (A.D. 780-850) and Al-Biruni (A.D. 973-1050) followed this practice. And, in the case of modern scientists

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**Jñānāmṛtam*, *Prof. A.C. Swain Fel. Vol.* Utkal University, 1985.

of the West, like Kepler, Newton Faraday, even their draft notes have been preserved. This feature of the Occidental documentation would enable one to understand the mental make-up of the Western scientists and to follow their arguments and achievements. Moreover, latterly, the study of science for science's sake has also taken roots in the Western tradition.

On the other hand, scientific documentation in India followed the *sūtra*-style of writing which required the scientist of depict his data and results in capsule form, leaving out the details and the rationale. The *sūtras* took the form of short pithy sentences, expressions and verses, with the result that the student was, more often than not, left in the dark about the mental working or the methodology of the authors of the *sūtras*. Moreover, science in early India was rather utilitarian, with the objective of solving a problem that had arisen or for serving a specific purpose; it was not science for science's sake. This outlook had the effect of the scientist cutting short his work at the stage at which his intended purpose was served and not proceeding further with his investigations. It is not as if no clue had been left for delving into the mind of the scientist and reconstructing his arguments and methods, but that requires retracing his path with effort by one who has full knowledge of the discipline and the modern analytic bent of mind.

Still another point to be noted is that though, in many cases, the results arrived at by the Western scientist and his Eastern counterpart were the same, the methods and procedures they adopted were often different. The stopping, by the Oriental scientist, of further investigations after a particular stage provides an opportunity for a modern scientist to strive further in that line, making new advances. In fact, such work is very much necessary towards utilizing fully the potential contained in the work of the early Indian scientist.

III. Sciences to be investigated:

The branch of science, which has the highest potential for a scientist and well versed in Sanskrit, is medicine i.e. *Āyurveda*. The vast sub-continent of India has an unparalleled wealth of flora and

fauna, both of which have been extensively used for medicinal prescriptions. For example, it has been analysed that the *Carakasaṃhitā* (c.A.D.100) mentions, as ingredients to medicinal preparations, as many as 177 substances of animal origin, 341 medicinal plants and plant products, and 64 minerals.[1] While some of these nearly six hundred substances have been duly identified and chemically analysed, a large number of them still remain to be so analysed and their curative properties verified and adaptations effected if and as necessary. In Ayurvedic literature, there are numerous texts prescribing for diseases, single drugs (*eka-mūlikā*) for specific ailments. The identification of the curative element in each of these drugs should be comparatively easy. Again, to take the case of minerals, Vāgbhaṭa (12th cent.A.D.) deals elaborately in his *Rasaratnakośa* (ch.IV. *Ratnāni*), with the medicinal aspects of gems and the curative properties of medicines prepared using their ashes. It has been established that a gem-like mineral called lizardite is the only effective remedy for the crippling disease of fluorosis.[2] In this wake, it should be worthwhile to investigate scientifically under controlled conditions the therapeutic properties of all the gems and their products.

As in the case of *Āyurveda*, Astronomy and Mathematics (including Arithmetic, Geometry and Trigonometry), in their development in India, have thrown out a number of ideas and approaches to various functions, many of which are worth being pursued further by Sanskrit-knowing mathematicians. To cite an instance; while Western trigonometry defines the Sine of an angle as the ratio of the side (opposite the angle) to the hypotenuse in a right angled triangle, the Indian Sine of an arc was defined as half the chord of double the arc in a circle of reference, the radius of the circle becoming the *Trijyā* or Sine of the three signs, i.e., the Sinus Totus (the total or complete Sine), Now, as many as 25 values have been used in Indian trigonometrical texts for the Sinus Totus from different points of view.[3] An analytical study of these values could bring our some new insights in the matter.

To take another example, to wit, the irrationality of π, being the relation between the diameter and circumference of a circle, it is interesting to note that the Power Series of π demonstrated by Lambert (A.D. 1671) and Leibnitz (A.D. 1673) had already been enunciated by Mādhava of Saṅgamagrāma (A.D. 1350-1411) more than three centuries earlier. Indian mathematicians have enunciated nearly a dozen formulae for derivation of π from different approaches. The rationalizations of these formulae in terms of modern mathematics have taken mathematicians to new vistas in mathematical thought.[4]

A few commentaries of mathematical texts go beyond explaining the *sūtras* and try to give the rationales underlying the *sūtras* which could help the Sanskrit knowing scientists. Thus, a commentary by Śaṅkara entitled *Yuktidīpikā* ('Lamp of astronomical rationale') on the *Tantrasaṅgraha* of Nilakaṇṭha,[5] supplies detailed rationales of the theory of numbers, division, square and square root, fractions, rule of three, diophantine equation (*kuṭṭākāra*), summation of natural numbers, squares and cubes, summation of summations, rules relating to triangles, circles and cyclic quadrilaterals and the surface area of a sphere. The same commentator, commenting on the *Līlāvatī* of Bhāskara[6] gives the rationales of squaring, square root, cubing, fractions, fractions of fractions, associated and dissociated fractions, multiplications and divisions of fractions, operations with squares, rule of three sides and hypotenuse in a right angled triangle, area of triangle, cyclic quadrilateral and the surface area and volume of a sphere. The point to note is that the approach in several of these rationales is different from the Western approach and therefore provides new directions for further advance to a Sanskrit knowing mathematician.[7]

Another potential discipline for a Sanskrit knowing scientist is *Śilpaśāstra* as enunciated in Sanskrit texts. Architecture and engineering, included in *śilpa* can, by no means, be compared to modern advances in these fields, But there are nuances which can add to the information and technical skill even of the modern engineer. Apart from novel structures and constructions, texts like *Śilparatna* of Śrīkumāra, *Aparājitapṛcchā* and *Samarāṅgaṇasūtradhāra* of King

Bhoja, specify a number of prescriptions and describe the method of preparation of several kinds of cement mixtures, adhesives, etc., which can form effective substitutes for costly building materials produced in present-day factories. It should be highly profitable for the building processes depicted in śilpa texts being tested and used by modern engineers who have a full knowledge of Sanskrit terminology and the capability of identifying building materials and preparing mortars and mixtures specified in ancient texts.

Among other fields, the enunciations and speculations wherein deserve to be more fully investigated upon, might be mentioned veterinary medicine depicted in works like the *Aśvavaidyaka* of Nakula, Śālihotra, *Hastyāyurveda* of Pālakāpya and *Mataṅgalīlā* of Nīlakaṇṭha, Nature cure and *Kāyakalpa* processes, *Svapnaśāstra*, *Sāmudrika-śāstra*, *Manovijñāna*, Extrasensory perception, etc. Scientists with knowledge of Sanskrit can also identify other fields for investigation, but the above might suffice to make the point.

The Desideratum:

What has been stated above would clearly point to the potentiality in the understanding, assimilating and making further use of the achievements of science as it developed in India. However, the traditional practitioner, with all the limitations of antiquated methodology, will fain be able to face this task. It is for the student of modern science to analyze early theories and practices, reconstruct their rationale and explain them in terms of modern science. He alone can make full use of what is offered by traditional science, by bringing to bear on it his knowledge of modern methods and facilities now available for experimentation and verification under controlled conditions.

Of recent, there is a welcome move to introduce in the curriculum of science studies in the different disciplines in universities the study of the history of Indian science. To be sure, such a study only through translations will have its own limitations. The texts have to be learnt, if such learning is to have its full effect, from their original

Sanskrit, which requires knowledge of the language. From this point of view, the relevance of the study of the Sanskrit language even by students of science, at the school and college levels, is highly apparent towards the utilization of that knowledge, later in tying up the loose ends of scientific ideas and practices that developed in India and carry the torch forward for new benefits.

NOTES AND REFERENCES:

1. *Caraka-saṃhitā: A scientific analysis*, by Priyaranjan Ray and Hirendra Nath Gupta, Indian National Science Academy, New Delhi, 2nd edn., 1981, pp.38-85.
2. *Proc. of the Fluorosis Symposium,* 2-5 Oct.,1974, Hyderabad, 1977.
3. R.C. Gupta, '*Indian values of the Sine Totus*', *Jl. of History of Indian Science*, (New Delhi), 13. ii (Nov.1978) 125-41.
4. K.V. Sarma, *A History of the Kerala school of Hindu astronomy*, Hoshiarpur, 1972), pp. 22-27.
5. Ed. by K.V. Sarma, Vishveshvaranand Institute, Hoshiarpur,1976.
6. Ed. by K.V. Sarma, Vishveshvaranand Institute, Hoshiarpur, 1974.
7. On this subject see also T.A. Saraswathi, '*Development of mathematical ideas in India*', *Indian Journal of History of Science*, 4 (1969) 59-78.

RESEARCH IN INDIAN MATHEMATICS AND ASTRONOMY: THE DESIDERATUM*

1. Indian Scientific tradition :

The scientific tradition in Indian civilization is, perhaps, as old as the civilization itself and is tellingly reflected in its literature and practices from the earliest times. Thus, for instance, one finds in several of the *mantras* in medicatory rituals, the indication of the symptoms, analyses of the diseases and of the properties of the drugs used. A very substantial part of the nearly 6000 *mantras* of the *Atharvaveda* are intended for use in medicatory rituals.[1] In the same manner, the several sacrificial practices and the *mantras* used therein provide glimpses of the mathematical and astronomical acumen that had developed during Vedic times. In this wake, there have been going on, during the Vedic and post-Vedic times, extensive scientific speculations, theorisations and practices, as attested to by the mass of literature, direct and indirect, produced during the period, in the several disciplines like Astronomy and Mathematics, Medicine, Alchemy, Agriculture[2] and the fine arts. In several disciplines, India had reached a more advanced stage earlier than other nations of antiquity, mainly on account of an analytical mind and logical thinking, aided by a fund of intuition. To cite an instance, while Greek mathematics was based on material mensuration and geometry, India transcended these steps early and devising the decimal system and the fundamentals of algebra, including the concept of zero and infinity and minus numbers and so more serious and abstract studies could be pursued.

2. Scientific literature in Sanskrit

The profusion, let along the profundity, of the scientific literature produced in early and medieval India is hardly realised and appreciated even by the Indologists and historians of literature, who, by and large,

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take Sanskrit and early Indian literature to be confined to Philosophy, Religion and the *belles letters*. To drive home the point, one might cite the case of texts on *Jyotiṣa* produced in the narrow coastal strip of Kerala in the extreme south of India. A survey of this literature has revealed the presence of manuscripts of as many as 752 distinct works composed by 111 authors.[3] Through a more elaborate survey of *Jyotiṣa* texts in Sanskrit at an all-India level, available in the repositories in India and abroad, David Pingree, author of *Census of the Exact Sciences in Sanskrit*,[4] could come upon about one lakh manuscripts on *Jyotiṣa* alone,[5] which might be taken to account for more than 5000 individual texts. In case of medicine in the *Āyurveda* and other systems, the number of works and manuscripts must be much more.

3. Relevance of ancient science today

The relevance today of an intensive study of early Indian scientific texts is three fold. The first reason, which is more of an academic nature, rests on its historical aspect. A study of this literature would, apart from picturing the development of the several scientific disciplines in India, enable one to compare it with the developments in the neighboring climes during contemporary times. Such comparative studies would help in the identification of the original contribution of each nation and also ascertain, to a fair extent, the mutual borrowings and influences. Secondly, it is often found that the Indian approach to a scientific problem is different from the Western, though both might have aimed at the same thing and obtained the same or parallel results, by different methods. In such cases, the study of the Indian scientific texts could enable the comparison of the methods towards suggesting alterations, as the case may be, for reaching quicker and more accurate results. Such comparisons could help also in bridging gaps in the steps for the derivation of results. The third and the most important relevance relates to the entirely new and hitherto unsuspected theories, methods and practices which would give a cue or twist or supply, a new line of thought to develop further modern practices or thinking on the subject, which a modern scientist with his background can easily pick up.

4. Mental make-up of the Indian scientist

However, for a fully accurate analytical understanding of an Indian technical text, the modern scientist shall require, in addition to

his scientific background, a fair knowledge of the Sanskrit language in which most early Indian technical texts are composed, and the ancient terminology rendered in terms of modern science. And, to understand the rationale implied in early works, one has to know also the material working of the authors of the texts, for, in most cases, the texts would be in the form of short aphorisms or aphoristic verses, giving the formulae, procedures and results without any indication as to how they had been derived. For, the scientific tradition in India had been that, though considerable experimentation, collection of statistics, analyses of results and step by step calculations had all been done, even as in modern scientific investigations, once the final result had been achieved, that alone was recorded in the form of cryptic *sūtra-s* and all the background material and calculations were thrown away, and naturally they got lost. This is in sharp contrast with the Western tradition in which even the rough material and draft notes were preserved for possible verification in the future. The result has been that it is a laborious process to trace back the arguments, experiments and calculational steps of the Indian scientists. But unless this is done, the *sūtra-s* of the texts would appear like arranged lists of formulae and procedures borrowed from elsewhere, possibly from alien sources, an impression that has been mooted and has gained ground, especially amongst Western scholars.

5. Retracing the Indian scientist's track

The task of divining the mind of the original authors and retracing the step by step paths which they had taken to arrive at formulae or procedures could be, as indicated above, laborious and time-consuming. Commentaries of technical texts are generally unhelpful in this matter, since they tend merely to explain the expression of the text and illustrate the processes rather than setting out the rationales thereof. Considerable ingenuity has therefore to be employed in unraveling the ancient author's mind. But the results would be commensurate with the trouble taken.

6. The Mathematical scientist

What has been stated above applies also to mathematical sciences which comprise of Astronomy, Trigonometry, both plane and

spherical, Geometry, Algebra and Arithmetic. Since sheer intellect is involved in a greater measure herein than in some of the other disciplines like Alchemy and Agriculture, it would be all the more instructive to probe the thought currents of the mathematical scientist, with which the present paper is primarily concerned. A three-pronged course of action is suggested in this regard.

a. **Commentaries**. While, as is generally the case, most of the commentaries merely explain the text, on a closer examination, it has been possible to identify a few commentaries which concern themselves also in setting out the rationales involved, which they call *yukti* or *upapatti.*

b. **Texts on Rationales**. The *Yuktibhāṣā* by Jyeṣṭhadeva, composed in Malayalaṁ, the language spoken in Kerala, has been well known to devote itself entirely to mathematical and astronomical rationale.[6] Of recent, it has been possible to identify and edit a few more texts of the type from the same part of the country.

c. **Short tracts on astronomical rationale.** Equally important are the single verses or groups of verses or prose expositions found written on the flyleaves or the margins or ends of astronomical manuscripts, giving mathematical or astronomical rationale. These extra-textual expressions have obviously been added by discerning users of the relevant manuscripts who have recorded their own findings or what they had heard from other sources or the special expositions given to them by their teachers. These passages go beyond the enunciation of principles and practices laid down in texts and aim at the logical presentation of the said principles and practices. Some of them take up individual topics as enunciated by different authorities, probe into the mathematical rules involved and try to establish the relative merits of each, thus taking the form of discussions and argumentations towards coming to a conclusion. It has been possible for the present writer to locate a few hundred rationalistic passages of this type from astronomical manuscripts in Kerala.[7] It should be possible to come across such passages in manuscripts from elsewhere as well.

7. Works on Rationale

Some of the works which have been identified as to contain astronomical and mathematical rationale, as indicated above, might be noticed here:

A. Astronomy:

1. Bhāskara I (c. A.D. 629) : Com. on the *Āryabhaṭīya*[8].
2. Govindasvāmin (c.A.D. 800) : Com. *Bhāṣya* on the *Mahābhāskarīya* of Bhāskara.[9]
3. Śaṅkaranārāyaṇa (c. A.D. 825-900): Com. Vivaraṇa on the Laghubhāskarīya of Bhāskara I.[10]
4. Bhaṭṭotpala (flourished A.D. 966): Vivṛti on the *Khaṇḍakhādyaka* of Brahmagupta.[11]
5. Bhāskara II (born 1114) : Com. *Vāsanā* on his *Siddhāntaśiromaṇi.*[12]
6. Sūryadevayajvan (born A.D. 1191) : Com. *Laghumānasa* of Muñjāla.[13]
7. Sundararāja (c. A.D. 1300) : Com. *Laghuprakāśikā* on the *Vākyakaraṇa* ascribed to Vararuci.[14]
8. Parameśvara (c. A.D. 1380-1460) : Supercom. *Siddhāntadīpikā* on the *Mahābhāskarīya Bhāṣya* of Govindasvāmin.[15]
9. Nīlakaṇṭha Somayāji (b. 1444)
   a. Bhāṣya on the *Āryabhaṭīya.*[16]
   b. Com. on his own *Siddhāntadarpaṇa.*[17]
   c. Co. on his own *Candracchāyāgaṇitam.*[18]
10. Śaṅkara Vāriyar (c. A.D. 1500-60) : Com. *Yuktidīpikā* on the *Tantrasaṅgraha* of Nīlakaṇṭha Somayāji.[19]
11. Gaṇeśa Daivajña (b. 1507 A.D.): Com. *Prakāśa* on the *Siddhāntaśiromaṇi* of Bhāskara II.[20]

12. Raṅganātha (fl. 1603 A.D.) : Com. on the *Sūryasiddhānta.*[21]
13. Kamalākara Bhaṭṭa (b. 1610) : Com. *Śeṣavāsanā* on his own *Siddhāntatattvaviveka.*[22]
14. Nṛsiṃha Daivajña (fl. A.D. 1621) : Com. *Vāsanāvārtika* on the *Siddhāntaśiromaṇivāsanā* of Bhāskara II.[23]
15. Minīśvara, (fl. A.D. 1627) : Com. *Marīci* on the *Siddhānta-śiromaṇi* of Bhāskara II. [24]
16. Mallāri (fl. A.D. 1751) : Com. on the *Grahalāghava* of Gaṇeśa Daivajña.[25]
17. Śaṅkara Varman (A.D. 1799-1839) : Com. in Malayalam on his *Sadratnamālā.*[26]

B. Algebra:

18. Kṛṣṇa Daivajña (fl. A.D. 1601) Com. *Bījapallavāṅkura* on the *Bījagaṇita* of Bhāskara II.[27]

C. Arithmatic, Goemetry:

19. Gaṇeśa Daivajña (fl. A.D. 1501) Com. *Buddhivilāsinī* on the *Līlāvatī* of Bhāskara II.[28]
20. Śaṅkara Vāriyar (c. A.D. 1500-60) Com. *Kriyākramakarī* on the *Līlāvatī* of Bhāskara II.[29]

D. Texts on Rationale :

1. Nīlakaṇṭha Somayāji (b. 1444). *Jyotirmīmāṃsā.*[30]
2. Jyeṣṭhadeva (c. 1500-75) *Yuktibhāṣā* or *Gaṇitayuktibhāṣā* (in Malayalam).[31]
3. Acyuta Piṣāraṭi (c. 1600) *Rāśigolasphuṭānīti.*[32]
4. Putumana Somayāji (c. 1660-1740) *Karaṇapaddhati.*[33]

Other commentaries giving rationales and texts devoted solely to rationales have to be identified from the mass astronomical and mathematical literature available, mostly in the form of Mnuscripts.

8. The Present Desideratum:

It has to be noted that during the last nearly one century, the academic stress in the field of Indian Astronomical and Mathematical literature, had been on the publication of texts and commentaries. As a result thereof, we have today many of the major texts available in print. It is time that due attention is paid to the rationale of the texts. The identification, understanding and setting out in logical steps, in terms of modern mathematics, early Indian methodologies and tracing the thought currents of the Indian Astronomer is the present desideratum. This is not to suggest that nothing has been done in this direction. The contributions of early scholars like Sudhakara Dvivedi, Bapudeva Sastri, Sukumar Ranjan Das, P.C. Sengupta, B.B. Dutta and A.N. Singh have paved the path, and a few modern scholars like Roger Billard (Paris), O. Neugebauer (Germany), R. Mercier (Southampton) and David Pingree (Providence, U.S.) from the west, and C.T. Rajagopal and his students including M.S. Rangachari and K. Balagangadharan and other, T.S. Kuppanna Sastri, K.S. Shukla, S.N. Sen, Bina Chatterji, the present author, A.K. Bag, T.A. Sarasvathi Amma, R.C. Gupta, Ramavarma Maruthampuran and P.K. Koru have strived in the same direction.

9. Researches to be undertaken

On the background of what has been stated above, it would be necessary that, for the coming ten or twelve years, say till A.D. 2000, planned programmes and projects are taken up by individual scholars, institutions and other agencies primarily for identifying and analysing mathematical and astronomical rationale. This work might be coordinated under the joint auspices of the Indian National Science Academy (INSA) and the National Institute of Science and Technology and Development Studies (NISTDS), New Delhi, for the reason that both these institutions have separate sections for History of Sciences, besides their possessing the necessary expertise, financial backing and experiences in the line. Both these institutions have long-range programmes, which are more or less oriented to the above-said desideratum and hence it might not be difficult for them to incorporate this type of work within their ambit. The work envisaged might be split up as follows :

i. The rationales as indicated in each of the commentaries, as available in print, be identified and explained in terms of modern mathematics.

ii. The rationales as available in texts devoted to rationales and stray verses and passages be similarly explained.

iii. All rationales, with their nuances, as identified and explained by earlier workers and as ascertained now, be consolidated and classified under different heads and topics, as the case might be. Such classification will enable the understanding of the working adopted in the different schools of astronomy and in the different parts of the country by different methods of tradition.

iv. The rationales so classified and coordinated be applied to the texts available in print but do not possess rationale-bearing commentaries, and the rationales therein duly explained.

v. Important unpublished texts and commentaries might now be selected and critically edited and translated and their rationales exposited on the background of the classified rationales.

In practice, the two coordinating bodies, the INSA and NISTDS might, together draw up lists of texts to be worked upon as indicated above, towards helping the individual scholars and institutions choose items suitable to them. Besides giving the necessary information and guidance, the coordinating bodies can also play a supervisory role in the conduct of the work and in coordinating the same.

10. Collaboration of Traditional and Modern Scholars

Last but not least, the quest after the early astronomers' path is best undertaken as a joint effort of pairs of scholars, one a scholar of modern astronomy and the other a traditional astronomer. May be, it is like the proverbial pairing of a blind man and a lame man, for mutual benefit. The first would know the methods and terminology of modern science and the latter would possess traditional acumen. Thus, the one would be a complement to the other. One would supply the lack of expression and terminology in the other, while the other would provide for the lack of knowledge in Sanskrit and the traditional ways of working. A combination of the two faculties in the same person would

be ideal, but difficult to come by. Then again, the pair will have the additional advantage of two types of scholars of different background and basic knowledge coming together and seeking to find the solution for a problem at hand.

NOTES AND REFERENCES :

1. See V.W. Karambelkar, *The Atharvaveda and the Āyurveda*, (Nagpur, 1861), and *Atharvavedic civilization* (Nagpur, 1959).
2. For a fair idea of these, see: D.M. Bose et al., *A Concise history of science in India*, Indian National Science Academy, New Delhi,1971; Satya Prakash, *Founders of sciences in ancient India*, Res. Inst. of Ancient Indian Sciences, New Delhi, 1965.
3. See, K.V. Sarma, *A Bibliography of Kerala and Kerala-based texts on Astronomy and Astrology,* Panjab Univerity, Vishveshvaranand Institute, Hoshiarpur, 1974.
4. Pub: American Philosophical Society, Philadelphia, Series A, vols., 1-4 (1970-1981),
5. 'At present, there exist in India and outside of it, some 1,00,000 manuscripts on the various aspects of *Jyotiṣaśāstra*', David Pingree, *A History of Indian literature: VI.4. Jyotiṣaśāstra ' Astral and Mathematical literature,* Otto Harrassowits; Wiesbaden, 1981.
6. The importance of this work was first brought to the notice of scholars by C.M. Whish in his paper "*On the Hindu quadrature of the circle and the infinite series of the proportion of the ircum-ference to the diameter exhibited in the four śāstras, the Tantra-saṅgraham, Yuktibhāṣā, Caraṇapaddhati and Sadratnamālā*", *Transactions of the Royal Asiatic Society of Great Britian and Ireland,* 3.iii (1835) 509-23.
7. Twenty seven of these tracts on astronomical rationale have been issued through the publication, *Gaṇitayuktayaḥ : Rationales of Hindu Astronomy* Pt.I, Vishveshvaranand Institute, Hoshiarpur, 1979, by K.V. Sarma.
8. Ed. K.S. Shukla, INSA, New Delhi, 1976.

9. Ed. T.S. Kuppanna Sastri, Govt. Or. Mss. Library, Madras, 1957.
10. Ed. P.K. Narayana Pillai, Univ. Or. Mss. Library, trivandrum, 1949.
11. Ed. Bina Chaterji, 2 vols. Calcutta, 1970. MLBD. Delhi, 1970.
12. Ed. Muralidhara Chaturvedi, Sampoornananda Skt. Univ. Varanasi, 1981.
13. Available in ms. form.
14. Ed. T.S. Kuppanna Sastri and K.V. Sarma, KSRI. Madras, 1962.
15. Ed. T.S. Kuppanna Śastri, Govt. Or. Mss. Library, Madras, 1957.
16. Ed. 3 pts. *Trivandrum, Skt. Ser.* 101,110, 185.
17. Ed. K.V. Sarma, Visveshvarananda Inst. Hoshiarpur, 1976.
18. Ed. K.V. Sarma, Visveshvarananda Inst. Hoshiarpur, 1976.
19. Ed. K.V. Sarma, Visveshvarananda Inst. Hoshiarpur, 1977.
20. Ed. Muralidhara Chaturvedi, Sampoornananda Skt. Univ. Varanasi, 1981.
21. Ed. with Hindi Tr. By Baldev Prasad Mishra, Kalyan, 1924.
22. Ed. Sudhakar Dvivedi and Muralidhar Jha, Varanasi, 1885.
23. Ed. Muralidhara Chaturvedi, Varanasi, 1981.
24. Ed. V.D. Apte, Poona, 1943 (An. Sanskrit. 122).
25. Ed. Ramachandra Pandeya, Ranvir Skt. Vidyapeeth, Jammu, 2 Pts. 1976, 1977.
26. Ed. K.V. *et.al.*
27. Ed. V.G. Apte, Poona, 1930. T.V. Radhakrishna Sastri, Sarasvati Mahal Library, Tanjore, 1950.
28. Ed. V.G. Apte, 2 Pts. Poona, 1937 (ASS. 107).
29. Ed. K.V. Sarma, Vishveshvarananda Inst. Hoshiarpur, 1975.
30. Ed. K.V. Sarma, Vishveshvarananda Inst. Hoshiarpur, 1977.
31. Ed. Ramavarma Maruthampuran and A.R. Akhileshvar Iyer, Mangalodayam Press, Trichur, 1947, Pt. I.
32. Ed. K.V. Sarma, Vishveshvarananda Inst. Hoshiarpur, 1977.
33. Ed. with notes by P.K. Koru, Astro Press, 1953, K. Sambasiva, Trivandrum (*Trivandrum Skt. Ser.* 126).

SCIENTIFIC BASIS OF INDIAN ASTROLOGY*

Astrology, being a science which aims at predicting the future, cannot fail to interest even the staunch nonbeliever. Whether it is to seek guidance on some matter of urgency, or to sort out remedies for current ills, or to take timely precautions against some impending calamity, or to avoid taking a false step in one's career, or at least, prompted by sheer curiosity, more people than who care to admit it, including the high-ups and the intelligentsia, continue to consult astrologers, every now and then. The evidence of the large number of periodicals, which are solely devoted to astrology, apart from the much more numerous ones which publish weekly predictions, is clear. If this is the position in India, things are not very much different elsewhere - the shade changes, but the substance remains. And, in the West, there has been, especially after the second World War, a sustained interest in astrology in its multifarious facets. It should, indeed, be profitable to take a close-up view of the matter and make some predictions on this science of predictions.

Astrology, which literally means 'the science of stars', can claim to be one of the earliest avocations of man. In India, it can be traced to the Vedas, where, in the *Taittirīya Saṃhitā* of the *Yajurveda* (1.5.2.1), mention is made of the 'auspicious star' (*puṇyaṃ nakṣatraṃ*) and the advantage of performing good acts when that star is rising. The *nakṣatra-darśa* 'star-gazer' and *gaṇaka* 'astrologer' were professionals even during Vedic times.

The causes which gave rise to the science of astrology are not far to seek. Now, things before us do not seem to follow strict logic, the law of cause and effect, of labour and reward. We see that human effort and freedom of will often miscarry. Apparently, there seem to be unseen forces which have a hand in these matters. Instead of ignoring these as freaks of nature or chance occurrences, the intelligent man evolved the science of astrology which seeks to bring all aspects of

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human activities within the range of planetary indication, physiognomical features, etc. The rules for astrological calculations have, naturally, been the result of minute classification and evaluation of a mass of statistical data, on a large variety of subjects, patiently collected under different conditions, over long periods of time, and, later, examined and analysed elaborately before generalizations were made. Vision and intuition, which involve a rather highly developed power of deduction, should have had their own part to play in the framing of the rules. The science has been subjected also to periodical additions and emendations, especially with regard to exceptions and new features. May be, planetary positions and physiognomical features do not really cause the results, but only indicate them empirically. But the soundness of the rules is proved by means of cross checking the simultaneous occurrence of the indicators and the results which they indicate.

If the profuse literature on astrology available today, in India, in Sanskrit and in the regional languages, in any guide, it would seem that India had been a very fertile ground for the growth of this science. Of the main sections of traditional Indian *Jyotiṣa,* the *Gaṇita-skandha* comprehends mathematics and astronomy, and the *Horā* and *Saṃhitāskandhas* constitute astrology. There, too, the *Horā* in its several sections like *Jātaka, Praśna* and *Muhūrta,* aims at predictions relating to the individual and the *Saṃhitāskandha* takes under its purview mundane or natural astrology in all its aspects. The two sages Parāśara and Jaimini are credited with the two main systems of astrology, of which the former has all India prevalence while the latter is popular only in the south. One aspect of astrology, viz. *Varṣa-phala* or 'yearly predictions' has come to be elaborated, in the 16th century, by Nīlakaṇṭha Daivajña in his well-known *Tājika-Nīlakaṇṭhī.* The *Praśna* branch of astrology, again, has been studied elaborately in Kerala, in South India. Among the eminent writers on Indian astrology might be mentioned the prolific Varāhamihira (A.D. c.500) who wrote the *Bṛhajjātaka* and the *Bṛhatsaṃhitā*; Śrīpati (born A.D. 999), author of the *Śripatipaddhati* and the *Jyotiṣaratnamālā*; Keśava Daivajña (born A.D. 1456), who is famous through his *Keśavapaddhati* and his son

Gaṇeśa Daivajña (born A.D. 1507) who was a prolific writer both on astronomy and astrology. A very interesting type of literature that came to be produced in predictive astrology is known as *Nāḍi-granthas* and are ascribed to different authorities like *Bhṛgu, Śukra, Agastya, Mārkaṇḍeya, Satya, Dhruva and Nandin.* The works of this class comprise hundreds of horoscopes of individuals of future generations and other specific or general subjects of the future with detailed predictions thereon. Naturally, these are consulted with unsalted interest by individuals, whose horoscopes happen to be found in these massive volumes.

However, if a rationalist thinker of today, to whom reason appeals most, seeing is believing, and the present is the reality, thinks twice before giving credence to astrology, he would be fully justified in doing so. In fact, that is exactly the manner in which he would react towards any other thing that does not fall within the range of his individual learning, experience and imagination. But these qualifications vary from person to person. To illustrate : While a qualified doctor can distinguish one from the other such ailments as fever, influenza, typhoid and pneumonia on taking a patient's pulse and temperature, the patient himself would be aware of nothing more than the rise in temperature. He might even stare in disbelief at modern medical science which can identify diseases like cancer, tuberculosis and leprosy which would affect him only several years later in life or which had affected him years ago. This is the logical attitude which a man of common sense would, naturally, take in the case also of apparently unaccountable predictions of astrology.

Under the circumstances, it would, indeed, be worthwhile to investigate the intrinsic worth of astrology and make such use of it, if any, as could be helpful to modern living. There are two ways of assessing a discipline which is apparently in its empirical stage or the steps in whose evolution are not very clear : First, to analyse and study the factors involved and secondly to verify the findings of the discipline with actual results. In fact, these are the methods employed for the evaluation of other seemingly intuitive traditional disciplines like *Yoga.*

Thus, the analytical experiments on yogic states conducted by institutions like the *Kaivalyadhāma* of Lonavala in Maharashtra, have served in seperating the real factors of *yoga* from the attendant ones and in making clear the significance of several yogic practices. Likewise, in the West, while the experiments of Neal Miller of the Rockfeller University have shown that man can control voluntarily even the supposed involuntary muscles, the experiments on bio-feedback conducted by the Menninger Foundation of Topeka (Kansas, U. S.) have shown that autogenic training or voluntary bodily control, which can be affected by yogic practices, can bring about changes in blood pressure, heart rate, muscular tension, brain waves and other biological functions-changes which could be directed towards the curing of bodily ailments and even in enlivening the intellect.

It would be equally worthwhile to subject the discipline of astrology to similar analysis and experimentation. May be, the analysis of astrology is more complicated than that of *yoga*, for more factors are involved herein. Personal equations might also crop in. However, a mitigating factor here would be the availability of a mass of material for correlation. Thus, the different branches of the discipline, like planetary astrology, numerology, palmistry, physiognomy, etc. as applied to the same person could be studied individually and comparatively. Thus, the findings of the said different branches of astrology on one and the same event or individual could be subjected to detailed analysis and correlations made. Substantial statistical data collected on a number of representative items studied in the light of the rules of the different branches of astrology, could, when properly classified and correlated, place the discipline on a proper scientific setting. Modern scientific explanations and corroborations might also have to be taken into account, when available. To cite an example: Indian astrology has predicted heavy upheavals in 1982, when an *Aṣṭagrahayoga* will occur, when all the planets will be aligned in a straight line. This prediction could be reinforced by very similar assertions made on purely astronomical and physical grounds by two modern

scientists, Gribbin and Plagemann in their recently published book entitled *The Jupiter effect* (Sept. 1974). The extension of the scope of astrology to spheres beyond those which have been envisaged by the ancient authors of the science could be done on the basis of findings from the study projected above. Or, has the process of extension started already, for an Institute of Atomic Astrology has recently been opened at Vanasthalī in Rajasthan, and a Committee set up by the Bangalore University has begun to investigate, scientifically and rationally, miracles, occult phenomena and verifiable superstitions. The interest in the West on similar investigations could be gauged from a round of Conferences and Seminars started mainly by American psychiatrists from April, 1976 to analyse life after death on the basis of the findings recorded by Dr. Raymond Moody Jr., in a book (*Life after Life; and reflections on Life after Life*) of his on the subject, which has run into three editions within a year since it was published in 1975.

DIRECT LINES OF ASTRONOMICAL TRADITION IN KERALA*

The importance of the transmission of knowledge from teacher to disciple is a characteristic feature of all civilizations during early times. Perhaps, it is more apparent and insisted upon in Indian tradition than elsewhere. Knowledge from the teacher's mouth (*ācāryamukha*) was the order of the day. Indeed, at a time when printing was unknown and books were scarce, this was a necessity. While it was possible for literature and philosophy to be imbibed, to a considerable measure, by self-study, there were subjects like music and medicine, which demanded practice and demonstration, making direct instruction essential. The discipline of astronomy falls under this category. Constant observation of the heavenly bodies, understanding of their motions by the use of the armillary sphere, deriving their positions by means of correlate computation with observation - all these required sustained personal instruction for a length of time, with the result that generations of dedicated teachers and pupils often fused into continuous chains.

In Kerala, that rather secluded narrow coastal strip of land in the southern tip of India, there developed some significant methodologies in astronomy and mathematics and more than one school of astronomical computation. It is interesting to learn about the several hereditary and other lines of astronomical tradition, prevalent in Kerala, more or less the nature of the *akhārās* for physical training and *gharānās* for practical music in North India.

The details of one such line of astronomical scholars is contained in an old palm-leaf document written in Malayalam script at the end of a manuscript of a Malayalam commentary of *Sūryasiddhānta* preserved in the Oriental Institute, Baroda (No. 9886). This document which is

Cārudeva Śāstri Felicetation Vol., Delhi, 1973.

undated and is composed in Malayalam and Sanskrit, gives information about a continuous line of scholars from Govinda Bhattatiri (born A.D. 1237) to Acyuta PiṣāraṭI (died 1621). The said document is reproduced here, with just the addition of indicatory numbers to the astronomers enumerated.

1. *Govindan Talakkuḷattūr Bhattatiri. rakṣet govindam arkaḥ ennu addehattinte jananakali. Keraleśvara-samipattu illam ākunnu.*
2. *Putumana-c-comātiri Karaṇapaddhati-karttā.*
3. *Parameśvaran Vaṭaśeri Nampūri. Nīlāyās saumya-tīrasthaḥ Parameśvaraḥ. Ayaṃ eva śakābdasaṃskāra-karttā.*
4. *Asya tanayo Dāmodaraḥ.*
5. *Asya śiṣyo Nīlakaṇṭhasomayājī. Iddeham Tantrasaṅgraham Āryabhaṭīyaṃ mulalāya granthannaḷkku kartāvākunnu. Lakṣmīśanihitadhyānaih ityasya kalinā kālanirṇṇayaḥ.*
6. *Pūrvoktasya Dāmodarasya śiṣyaḥ Jyeṣṭhadevaḥ. Iddeham Paraṅkoṭṭu nampūriyākunnu. Yuktibhāṣā-granthatte uṇṭākiyatum iddeham tanne.*
7. *Jyeṣṭhadevante śiṣyan Tūkkaṇṭiyur Acyuta Piṣāraṭi. Iddeham Sphuṭanirṇṇayam, Goladīpikā mutalāya grantha-karttāvākunnu.*
8. *Acyuta Piṣāraṭiyute śiṣyan Meluputtūr Nārāyaṇa Bhaṭṭatiri. Iddeham Nārāyaṇīyam, Sarvvasvam mutalāya granthannaḷkku karttā. Āyurārogyasaukhyam itādikalinā kālanirṇṇayaḥ.*
9. *Mādhavan Ilaññippalli Emprān Veṇvāroham, Muhūrttamādhavīyam Praśnamādhavīyam mutalāya granthannaḷkkum, Agaṇita- pañcā gattinum karttāvākunnu.*
10. *Brahma-Sūrya-Vasiṣṭha-Romaśa-Pauliśāḥ pañca Siddhānta-karttāraḥ.*
11. *Mayo 'pi Sūryasiddhāntasya praṣṭṛtvāt karttā.*
12. *Garggaḥ eteṣām samānakakṣyatvāt so 'pi pūjyatamaḥ.*
13. *Śrīpatiḥ Siddhāntaśekhara-Śrīpatipaddhatyādīnām karttā.*

14. *Lallaḥ Śisyadhīvūddhidam iti prasiddhasya tantrasya karttā.*

15. *Muñjālako Mānasa-karttā. Mānam eva Laghumānasam.*

16. *Govindo Muhūrtharatnādīnām karttā.*

17. *Parameśvaraḥ Dṛgganita-karttā iti śrutam mayā.*

Item 1-9 and 16-17 in this document refer to Kerala astronomers and its trustworthiness has been attested to by the details mentioned therein having been confirmed, except for a point or two, by evidences mostly contained in the works referred to in the document.[1] The document informs us that the date of Govinda Bhaṭṭatiri, author of *Muhūrtaratna*, is Kali day *rakṣet Govindam arkaḥ* (1564362, in A.D. 1237). Parmeśvara, the Vaṭaśśeri Nampūtiri, author of *Dṛgganita*,is the father of Dāmodara. Dāmodara's pupil was Nīlakaṇṭha Somayāji, who wrote the *Tantrasaṅgraha*, *Āryabhaṭīya-bhāṣya* and other works His pupil was Jyeṣṭhadeva, was the author of *Yuktibhāṣā*. His pupil was acyuta Piṣāraṭl who wrote the *Sphuṭanirṇaya* and other works. This genealogy, as set down below with the dates and some links supplied from other sources, may be seen to cover a span of nearly 400 years: Govinda Bhaṭṭatiri (1237-95) → pupil : Grandfather of Parameśvara[2] (13^{th}-14^{th} cent.) grandson-pupil : Parameśvara (c. 1360-1455) → son : Dāmodara (15^{th} cent.) → pupil : Nīlakaṇṭha Somayāji (1444-1545) → pupil : Jyeṣṭhadeva (1500-1600) → pupil : Acyuta Piṣāraṭi (1550-1621).

An eighteenth century astronomer Kṛṣṇadāsa (Mal. Kṛṣṇan Āśān), author of a *Pañcabodha, a Jāthakapaddhati*, a commentary of the *Daśagītisūtra* of the *Āryabhaṭīya*, etc., all in Malayalam, gives in his work entitled *Āranmuḷa-vilsa*, the genealogy of his teachers, right from Acyuta Piṣāraṭi, in the following lines :

Rāman ennellāṭavum viśrutanāyiṭṭabhi-
rāmanāmāśāsitāvennuḷḷa kīrttiyoṭum ।
guru-daivajñanmārkkum gurubhūtanām ente
guruvām pitāvinṭe caraṇāmbujam vande ।।

guruvin guru Vyāghramukhamandiravāsi
gurukāruṇyaśāli tanneyum vaṇaṅṅunnen
tadgurubhūtanāyiṭṭetrayum manīṣiyāy
hṛdgatabhāvajñanāy gaṇita-tattvajanāy ।
tāzhāta kīrttiyoṭum Nāvāyikkuḷattuḷḷor
Āzhātipravaranām guruve vandikkunnen ॥
Āyavan tanṭe gurubhūtanāyuḷḷa deham
āyatamatikaḷāl pūjitan āyuḷḷavan ।
Kolattunāṭṭu Tṛppnikkare Potuvāla-
kkālattegguruvaranmāril vaccagresaran ।
ennuṭe guruvinṭe guruvin gurubhūtan
tannuṭe guruvākum tapadam vaṇaṅṅunnen ॥
Potuvāḷinte guruv-Acyuta Piṣāraṭl-
yatimānuṣan avan sakalavidyātmakan ।
anpattimūnnu vayassiraṭṭiyirunnuḷḷa
Melputtūr Paṭṭerikkum guruvāyirunnavan ॥
tannuṭe padapadmayugaḷam viśeṣiccum
ennuṭe manakkāmpil santatam ninaykkunnen ॥[3]

For the tradition represented here see p. 129.

The three tables set out above, together form, in fact, one continuous chain of astronomers, whose period extends over six centuries, from 1237 to 1846. It is possible to identify in the annals of Kerala astronomy several shorter lines of teacher-pupil succession and instances of direct and indirect patronage to this set-up. If Kerala has made any impact in the history of Indian astronomy during the medieval times, due credit for his distinction has to be given to the academic succession of the exponents of this discipline.

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1 See K.V. Sarma, '*Oru jyotiṣa-granthavari*', *Mātrubhūmi*, (Malayalam Weekly, Kozhikode), 19-5-1957.

2. For this relationship, see Parameśvara's own words towards the beginning of his commentary on the *Muhūrtaratna* of Govinda :

Govindapūjyapādena kṛpāsaṃsiktacetasā ।
muhūrtāgamadugdhābdheḥ Muhūrtamaṇir uddhṛtaḥ ॥
tasmiṃs tacchiṣyapautreṇa kiyāṃścid Paramādinā ।
bhāgo vivriyate svalpam Īśvareṇa yathāśrutam ॥

(Ms. Kerala Univ., Mss. Lib. T.144)
(Parama-ādi Īśvara=Parameśvara)

3. See K. Śaṅkara Menon, Intro. to his edition of the *Bhāṣājātaka-paddhati*, (Trivandrum, M.E. 1101); Ulloor S. Parameśvara Aiyar, *Kerala Sāhitya Cahritram*, Vol.II, (Trivandrum, 1954), pp.321-22.

4. *Ibid.*

THE MEANING OF TIME IN ANCIENT INDIA

Ancient India: The Need for Calendars

Every expedient contrived by every civilization can be traced to meet the needs of times. So was it in India too with regard to the evolution of the Calendar, during pre-historic times and its ramifications during later ages. To the '*Hindu*', the man in India over which was apread one of the earliest civilizations of the world, 'Time' never stood still. The *Veda*-s, which form the basic religious texts of the Hindus, of which the *Ṛg-veda*, containing over 10,000 chants composed in pre-classical Sanskrit, before 3000 B.C., portrays a highly sophisticated and socially advanced society. The Vedic society was strictly wedded to manifold rituals and long sacrifices which had been ordained to be performed at specific times and at regular intervals based on the appearances and movements of the sun, the moon and the stars, the equinoxes and solstics, lunar days and months, the seasons and the like. It is no wonder therefore that efforts were made towards understanding and predicting appropriate times for the varied religious observances through easily workable, easily remembered and sufficiently accurate calendars resulting in the production of two full-fledged texts, both called *Vedāṅga-Jyotiṣa* (Vedic Astronomy), one relating to the *Ṛgveda* (ṚV) and the second to *Yajurveda* respectively.

Astronomical observations:

(i) *Nakṣatra-vidyā*:

The *Veda*-s and their secondary texts though primarily directed towards religious and ritualistic activities, on account of their immense extent, running to several thousands of verses inter spread adumbrated with prose, are highly varied in their contents and diversified in their descriptions. They also place before us a pen-picture of every aspect of the Vedic society, their way of life and thinking, social strata, rituals and sacrifices, teachings and studies, sports and pastimes, the prevailing arts and sciences get depicted in some manner or in some

context. The sciences include obviously astronomy as well, which went under the name *nakṣatra-vidyā* or 'Science of Asterisms' (*Chāndogya Upaniṣad* (7.1.2.4) practiced by the *Nakṣatra-darśa* or 'Star-gazer' (*Yajurveda Vāj. Saṃ.* 3.10 and 3. 20, *Tai. Br.* 3.4.4 and 3. 4. 15) and the Mathematician the *Gaṇaka* calculator. Their experimentations and results achieved find mention in Vedic texts sometimes expressly and sometimes euphemestically. It is also interesting that Vedic literature has many things to say about the findings of these pre-historic astronomers who plied their trade with their sharp naked eyes, assiduously through intense observation and for a long times.

(ii) Earliest Astronomical observation

(a) Vedic Astronomers:

In tune with the developments mentioned above, several families of astronomers grew up among Vedic priests, the most outstanding among them being the sages of the *Atri* clan noted for their reckoning eclipses and a whole Ṛgvedic hymn (5.40) on a total solar eclipse has been devoted. The Vedic text *Taittirīya Brāhmaṇa* (3.10.9) mentions several experts in astronomy. They include King Janaka, Ahina son of Aśvattha, the sacrificer Devabhāga and Śuṣa, son of Vārṣṇī. The efforts of these astronomers had been to identify the celestial bodies, measure their movements by themselves or in relation to others for reckoning time nuances and the formation of calendric framework. These details of the endeavours of the Vedic astronomers are gleaned from general descriptions or portrayals of sacrifices, sometimes from plain statements and at other times from involved or cryptic expressions.

(b) Deductions from observations

The sun was conceived as the sole lord and light-giver of the universe (*ṚV* 8.58.2) and the prime supporter of the world (*RV.* 1. 164.14) and moves along a broad pathway (the ecliptic) chartered by God Varuṇa (*ṚV.* 1.24.8). The moon is conceived as one which shines by the rays of the sun (*Taittirīya Saṃhitā* 3.47.1) and appears in new

forms day by day (*ṚV.* 10.85.19) each of the forms being given a separate name. The Moon moved on the same path as the Sun, from west to east. New moon and full moon had been conceived as the moon being swallowed part by part, day by day, by the demon Rāhu and released in the same manner as explained in the Vedic text *Aitareya Brāhmaṇa* (40.28). Rising on the horizon would be obscured by the gale of the sun, the *Taittirīya Brāhmaṇa* (1.5.2.1) specifies that the preceding star should be looked for and by time adjustment the rising time of the required star should be computed. To distinguish the planets from the stars was not a problem for the Vedic astronomer. In fact all the five planets had been identified and given distinct names (*Atharvaveda* 19.9.7-9).

Through constant observation the Vedic astronomers also identified the equinoctial days when day and night were of equal duration, and also the solstitial days when the sun commenced its southward and northward movements. (*Tait. Saṃhitā* 6.5.3).

(c) Some fundamental observations.

The Vedic astronomers noticed that also as the Moon coursed through the stars spread over a broad belt, as it were, in the sky, and that it returned to its starting place once in 27 days. It was also noticed that on any specific day among these 27 days, in any cycle, the Moon was among the same set of stars. Those sets of stars were termed asterisms with specific names. This gave rise to the concept of the zodiacal belt divided into 27 asterismal segments. Observation, again, showed that the Sun too coursed along the same path (zodiac) and that it covered a twelfth portion of the Zodiac in 29.1/2 days. (once it had commenced its journey at which turn it was abreast of the Moon on the new-moon day). This gave rise to the concept of the lunar month of 29.1/2 days. It was also ascertained that the Sun came, reached back or returned to its starting point on the zodiac in 365-odd days giving rise to the concept of the 12 signs of the zodiac. Here again the stars in each segment formed the figure of an animal or object on the basic of which a name also given to each of the twelve zodiacal segments, like *Meṣa* (Aries), *Ṛṣabha* (Taurus) etc.

Time division in the *Veda*

The basic units of time of the Vedic Indian were the year (*saṃvatsara*) and the yuga of five years (*Tait. Br.* 3.10.4). The year was reckoned as 360 full days or 720 days and nights. The twelve months consitituted six seasons (*Tait. Saṃ.* 4.4.11). For specification in sacrifices the days and nights of the dark and bright halves of the months carried specific names (*Tait. Saṃ.* 3.10.1-3). Again, for the self-same purpose the days and nights were divided into two, three, four or five and fifteen parts and each fifteenth part was further divided into still further fifteen parts. (*Tait. Br.* 3.10.1.1-4).

It is, however, necessary to keep in mind the purpose for which the ancient Indian astronomer kept on making observations and computations. These were actually being done towards the ascertainment and fixation of appropriate times for the performance of daily, seasonal, occasional, annual or even life-long sacrifices which were enjoined in the Vedic texts for attaining the present heaven after the current life or for reaping mundane benefits during earthly life.

Yuga system of the *Veda* and Time reckoning

Astronomical observations carried on as indicated above enabled the evolution in Vedic India of a Time-cycle called *Yuga* ('collection'), each of five years' duration. This system is exposited in a full-fledged manner in the *Vedāṅga-Jyotiṣa* ('Astronomical ancillary of the *Veda*'), a work essentially intended as a handbook of postulations and formulae for the Vedic priest towards the determination of appropriate times for rituals. All the same, it contains, inter-alia, coded information on the entire gamut of Time reckoning in vogue during the Vedic age in India. According to this text each *yuga* consisted of five solar-sidereal years, equal also to 60 solar months, 67 lunar-synodic months, 1830 solar days, 1885 sidereal days, 1860 lunar days and 62 synodic months. Each *yuga* commenced when the Sun and the Moon rose together at the winter solstice which began with the northward progress of the sun at the commencement of the then lunar month. For the sake of easy in recollection and calculation the above figures had

been given accurate to the units. However, suitable compensations were made by actual observation. Then again, an intercalary month was introduced at the beginning of the yuga and at the end of the second year. These two made up for the error in the scheme and prevented the error from being carried forward.

Time measures during the later *Yuga* system

Towards the beginning of the Christian era Time-measures using Vedic astronomy which had been designed for rituals gave place to a scientific reckoning of time based directly on the movements of the Sun, Moon, Planets and the Earth. Naturally the introduction of this system had been preceded by considerable computations and observation of the sky both with the naked eye and through astronomical instruments. Five different texts depicting these systems, called *Siddhānta*-s, have been condensed by the 6th century astronomer Varāhamihira in his work called *Pañcasiddhāntikā*. The foremost astronomer of this genre is Āryabhaṭa, born in A.D. 476. In his two works entitled *Āryabhaṭīya* and *Āryabhaṭasiddhānta*, he depicted the different aspects of astronomical computation and observation and also gave a description of the astronomical instruments used. In the former work Āryabhaṭa identifies a date corresponding to Feb. 18, 3102 B.C. when the Sun, Moon and all the planets were together at one place, for which reason it was taken as the Zero date from which all further dates were to be reckoned. It was taken as the date of the commencement of the *Kali-yuga* ('*Yuga* of *Kali*'). Time reckoning was made extremely simple and definitive by this scheme since at sun-rise on that day had occurred the transit of the Sun into the zodiacal segment of *Meṣa* (Aeris) and also the beginning of the light half or new-moon. (*Āryabhaṭīya* III.10).

Endless Time

Time according to ancient Indian tradition is endless. It has no beginning, nor has it an end. However, for practical purposes, like those relating to history, daily life and social transactions defenitive datings were required and that need was fulfilled by measures

computed by means of the revolutions of the Sun, Moon and the celestial bodies and expressed in terms of the *yuga*, year, month and day. The largest unit in the scheme was the *kalpa* which was taken to constitute one day of God Brahmā, the Creator of the universe. A *kalpa* was counted as equal to 1008 *yuga*-s or 14 Manu periods of 72 *yuga*-s each, the length of each *yuga* being 43,20,000 years. The *yuga* is divided into four equal parts, each of 10,80,000 years, called *Kṛta, Tretā, Dvāpara* and *Kali*. At the present time 6 Manu-s and 27 3/4 *yuga*-s have passed by and the universe is in the last quarter of the 28th *yuga*. Āryabhaṭa's this *yuga* scheme is popular in South India.

Time in Indian Mythology

Certain other astronomical texts like the *Sūryasiddhānta*, which latter is extremely popular in North India, follow: the *yuga* classification depicted in Indian mythological works like the *Purāṇa*-s and books on social law like the *Manusmṛti*. Herein also the main divisions are called *kalpa*, *manvantara* and *yuga*, but the lengths of these divisions are very much different. Also the *yuga* divisions are not of equal length as in Āryabhaṭa but are in the proportion of 4, 3, 2 and 1. According to this scheme one day-time of the Creator Brahmā is one *kalpa* and the night takes up a second *kalpa*. Each *kalpa* contains the periods of 14 *Manu*-s, each of which has a distinct name. The Creator's life-span is 1008 *Mahā-yuga*-s 'Great *yuga*', each made up of the four *yuga*-s *Kṛta, Tretā, Dvāpara* and *Kali*, in the proportion 4: 3: 2: 1. 360 day-nights of Brahmā make up a *Brahma*-year which is equal to 720 *kalpa*-s. The life-span of Brahmā is 100 years of the above said measure. It is also presumed that at the commencement of the current *kalpa*, Brahmā had completed 50 years, so that the present *kalpa* is the first day of the 51st year of Brahmā. Herein the durations of 6 *Manu*-s have passed by as also a part of the 7th *Manu* when the current *Kaliyuga* commenced.

Āryabhaṭa has, in his scheme, dispenced with the complicated *yuga*-system of Indian mythology and has devised the simple system described earlier aiming at ease in its application. However, in actual practice the two systems have been so adjusted that the

commencement of *Kaliyuga* is the same in both, viz., Feb.18, 3102 B.C. so that the dates of an ever connected by both the two systems would be the same.

Time in Religious life

It is not generally known that the Indian of early times had a penchant for the declaration of 'Time' in every religious act of his, not only the 'Time' but also the 'Place'. For instance, before commencing any of a religious nature one had to pronounce a *saṅkalpa* or declare one's intent indicating in detail the time and place of the act. This age-old practice continues even today among the *brāhmaṇa*-s of the land. Thus if one were to offer libations to one's ancestors on the new-moon day, one has to pronounce his intent in such words as the following:

'Today which occurs in the second half of the first day the lifespan of the creator, in the *kalpa* called *Śvetavarāha*, when the 20th period of the 28th *Manu* in which the first quarter of the present *Kaliyuga* is current, at the southern portion of Bhārata (India) continent included in the Jambū Island, in the current *Śaka* year named *Iśvara* from amongst the sixty year-cycle, in the month of *Dhanuṣ*, when the sun is in its southern progress, on the holy new-moon day, on Friday when the constellation is *Punarvasu* I shall be performing the ritual due to my ancestors and alongside, I shall also be offering them libations of water mixed with sesame seeds'.

While the above is a short Recital of Intent it has been ordained that much longer and more elaborate Recitals should precede the performance of domestic rituals like the sixteen sacraments (*saṃskāra*-s). The longest Recital of Intent is made to precede the ritual of the 'Rededication to the *Veda*' performed on the full-moon day of the month of *Siṃha* under the asterism *Śravaṇa*.

Time in Indian Religion

An essential point to note with regard to Indian life over the centuries is that Time and the science used for its computation, namely,

Astronomy had been inextricably integrated with Astrology which was the science for computing Muhūrta or 'Auspicious time'. The *muhūrta*-s computed on the basis of the movements and relative positions of the Sun, Moon and the planets govern every aspect of Hindu religious life. Indeed from the moment of getting up from bed at pre-dawn (*Brāhma-muhūrta*) the Hindu follows the law-precepts for every aspect of his personal, social and professional-activity. His bath, prayer, giving gifts, wearing new clothes, an even cutting his hair are governed by the selection of muhūrta-s for the act. Commencement at the correct *muhūrta* is a must for all rituals which abound in Hindu religious life. Agricultural activities like ploughing, sowing, manuring, reaping and even storing the grain, had to be done at auspicious times. For the construction of houses temples and other structure and for repairing them auspicious times were availed of. In money matters including lending and borrowing *muhūrta*-s come into play. The same is the case in matters like entering politics, purchasing cattle, commencing a journey, planting trees, digging canals and even for waging war the proper *muhūrta* is to be sought for. Ultimately a Hindu cannot live away from 'Time' in any sphere of worldly life.

Difference of Time in Modern Europe

Till about two-odd centuries from when the Western culture percolated into the civil calendar in India the concept and connotation of Time was entirely different in India. Apart from all the distinctness and differences made mention of earlier, even in telling time by means of the year, month, day and hour India followed its age-old pattern. Apart nomenclatures even in the use of time measures including the number of days in the twelve months of the year it was different from that in the West. In India the day consisted of 60 *nāḍi*-s each *nāḍi* being made up of 60 *vināḍi*-s and each *vināḍi* being equal to 60 syllables of these measures, what was mostly common in use were the year, month, day, *nāḍi* and *vināḍi*, the mostly common in use were the year, month, day, *nāḍi* and *vināḍi*, the correspondence of the last two in terms of modern time-measures being: One hour is equal to 2 1/2 *nāḍi*-s and one minute is equal to 2 1/2 *vināḍi*-s.

Meaning of Death and Eternity

All said and done, Indian tradition has postulated from the earliest times that 'Time' is eternal. It has no beginning nor end. It is a continuum. It is also emphasized that there is no 'real' death. Destitute and destruction is only for the physical body (*deha*) and not for the individual soul (*jīva*) which inhabits the body. When the body dies the soul leaves that body and occupies another new-born body and when that body too dies the soul migrates to a third body which is newly born. The process goes on the individual through the course of endless time unless the individual soul is absorbed into the 'One Permanent Soul'. As the *Gītā* which is the Bible of Hinduism states euphemistically, death and birth of the physical body is only like casting off of a soiled dress and donning a new dress to the imperishable soul. When a soul migrates to a new body it carries with it the load of merits it had gained and the demerits accrued through its sinful acts to the new body to which it migrates. While it enjoys the fruits of the merits and suffers for the sins it had carried with it, it goes on accumulating new merits and sins. While it uses up some of these while inhabiting the new body, when that body dies the remnant is carried forward to another new body which it would occupy.

It is to be noted that para-psychology and clairvoyance have proved the ten ability of the above theory which duly explains the vast differences seen between man and man in the world. The theory is also verified by several people recognising places and persons with whom they had been acquainted with during previous births and also recollecting past experiences. Faith in the reincarnation of the soul after the death of the physical body has sustained, through centuries, the faith in the Indian in an ever bright future and has also enabled him to lead a life of quiet contentedness free from tension, worry and suspense which affect the people in most parts of the world. But for a minuscule of modernized urban population, the common man in India has perfect trust in the theory of Reincarnation and Eternity of time, which conduce to his life of inner peace and quititude.

PART - II

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Abbreviations

ABORI	Annals of Bhandarkar Oriental Research Institute, Pune.
AIOC	All India Oriental Conferences (Proceedings)
AMM	American Mathematical Monthly
AS	Annals of Science
BCMS	Bulletin of the Calcutta Mathematical Society
BM	Burlington Magazine. London
BNISI	Bulletin of National Institute of Science of India.
IGNCA	Indira Gandhi National Centre for Arts, New Delhi
IHQ	Indian Historical Quarterly, Calcutta
IIAS	Indian Institute of Advanced Study, Shimla
IJHS	Indian Journal of history of Science, New Delhi.
INSA	Indian National Science Academy, New Delhi
JAOS	Journal of American Oriental Society, New Haven (USA).
JASB (NS).	Journal of Asiatic Society, Bombay (New Series)
JBBRAS	Journal of the Bombay Branch of the Royal Asiatic Society, Bombay
JBORS	Journal of the Bihar and Orissa Research Society, Patna
JBRS	Journal of the Burma Research Society, Rangon.
JDL-CU	Journal of the Dept. of Letters, Calcutta University
JIBS	Journal of Indian and Buddhist Studies, Tokyo (Japan)
JORM	Journal of Oriental Research, Madras
KSRI	Kuppuswamy Shastri Research Institute, Chennai
MLBD	Motilal Banarsidass, New Delhi
QJMS	Quarterly Journal of Mythic Society, Bangalore
TSS	Trivandrum Sanskrit Series, Trivandrum, Kerala
VVRI	Vishveshvaranand Vedic Research Institute, Hoshiarpur
ZDMG	Zeitschrift der Deutscen Morgen landischen Gesellschaft, Wiesbadon (Germany)

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